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SOME FUNDAMENTAL PROPERTIES OF NEPHELINE SYENITE*

By C. J. Koenig

Abstract

The fundamental properties of nepheline syenite, such as thermal expansion and fusion characteristics, are given. Test specimens of twelve bodies, comprising various flux combinations of nepheline syenites and potash feldspars with talc, whiting, magnesium carbonate, and pyrophyllite, were fired to seven different cones. The firing linear shrinkage curves of combinations of nepheline syenite with the various materials are somewhat similar to such combinations with potash feldspar except that the syenite combinations are active at lower temperatures. That the sintering ranges of nepheline syenites are longer than those of potash feldspar is explained thermochemically.

I. Introduction

Nepheline syenite is an igneous rock, somewhat resembling granite in texture, hardness, and general appearance. The chief minerals comprising this rock are nepheline, potash feldspar, and soda feldspar, with various accessory minerals. It contains little or no free quartz. The mineral nepheline ($Na_2O \cdot Al_2O_3 \cdot 2SiO_2$) crystallizes from the molten magma instead of soda feldspar as a result of an insufficient amount of silica in the magma to form feldspar.

II. Empirical Formula

The molecular formula of Blue Mountain nepheline syenite rock[1] is 0.75 Na_2O, 0.25 K_2O, and 1.1 Al_2O_3 and 4.5 SiO_2; the combining weight is 452.

III. Fusion Characteristics

Fusion characteristics were obtained by the inclined plane test, firing at the rate of 55° to 60°F per hour in a gas-fired downdraft kiln.

A sample of Blue Mountain nepheline syenite was ground to about 3% on 200-mesh and divided into coarse, medium, and fine with a Federal laboratory air classifier. The average particle size of the coarse division was 55 microns, 13 microns in the medium, and 3 microns in the fine division. The Al_2O_3 content of each division was coarse 24.60%, medium 24.31%, and fine 24.14%.

Table I

Chemical Analysis of Raw Materials

Oxides	N.C. potash feldspar (*a*)	Blue Mountain nepheline syenite* (*b*)	Nepheline syenite (*c*)	Nepheline syenite (*d*)	Talc (*e*)	Pyrophyllite (*f*)
SiO_2	67.68	59.30	48.92	52.44	54.5	75.30
Al_2O_3	18.87	24.70	31.69	28.65	1.3	20.74
Fe_2O_3	0.054	0.06	0.10	0.09		0.08
TiO_2		0.002	< 0.01			
CaO	0.49	0.27	0.86	1.24	6.5	0.08
MgO		0.02	0.06	0.10	30.7	
Na_2O	2.78	9.91	13.70	12.87		} 0.21
K_2O	10.74	5.10	4.06	4.01		
Ignition loss	0.17	0.44	0.43	0.68	5.5†	3.67
Total	100.784	99.802	99.97	100.08	98.50	100.08
Mesh No.			Screen analysis			
180		0.05	0.07		0.12	
200	0.90	0.28	0.42	0.69	0.16	0.50
240		0.37	0.53		0.25	
270	2.30	1.58	0.95	2.00	0.39	
325		3.90	1.88		0.45	4.80

* See footnote 1.

† Water content variable within limits.

Table II

Material	Divisions of flow on inclined plane
N. C. potash feldspar (*a*)	0
Blue Mountain nepheline syenite (*b*)	1.6
Nepheline syenite (*c*)	1.0
Nepheline syenite (*d*)	2.0

Figure 1 shows the relative fusibilities resulting from variable particle sizes of Blue Mountain nepheline syenite.

IV. Thermal Expansion

(1) Preparation of Specimens

Because these materials are nonplastic, an organic bond dissolved in distilled water was added to facilitate plastic forming. Prior to the determination, the

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* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 29, 1938 (White Wares Division). Received April 16, 1938.

[1] The name "Blue Mountain nepheline syenite," used throughout in these papers, has been changed to "Lakefield nepheline syenite."

organic bond was removed by firing to cones 09 to 08. Fused quartz expansion apparatus was used.[2]

(2) Discussion

Linear expansion values are given in Fig. 2. The thermal expansion of nepheline syenite is greater than that of potash feldspar. The presence of free

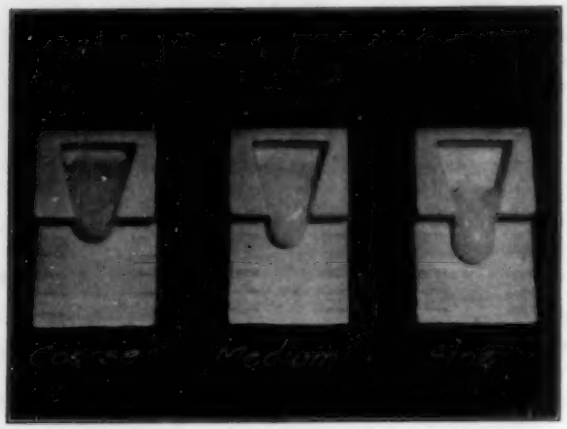

FIG. 1.

quartz in the potash feldspar caused a deviation at about 573°C (the inversion point of alpha to beta quartz), whereas the expansion curve over this range for nepheline syenite is smooth.

V. Body Trials

(1) Preparation of Bodies

The materials were weighed (4000 grams) and dry-mixed in ball mills for two hours (see Table III). Thirteen per cent of a 2% solution of gum tragacanth in distilled water was added, thoroughly mixed, and passed three times through a 10-mesh screen. The

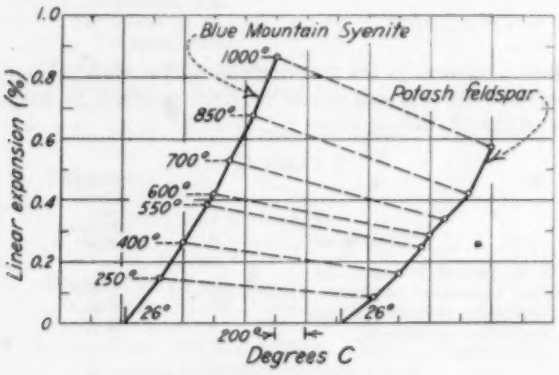

FIG. 2.

batches were placed in closed containers for a period of 3 to 4 hours before forming the test pieces. These pieces were 1 by 2 by 4 inches; the forming pressure was 500 lb. per sq. in.

[2] P. Hidnert and W. T. Sweeney, "Thermal Expansion of Magnesium and Some of Its Alloys," *Bur. Stand. Jour. Research*, **1** [5] 771–92 (1928); *Ceram. Abs.*, **8** [1] 65 (1929).

(2) Firing

Firing was conducted in a gas-fired downdraft laboratory kiln at a rate of approximately 50°F per hour. After soaking for one hour, the gas was turned

TABLE III

Body No.	
(1)	N. C. feldspar (*a*)
(2)	Blue Mountain nepheline syenite (*b*)
(3)	Bancroft nepheline syenite (*d*)
	(%)
(6)	75 Blue Mountain syenite (*b*) 25 N. C. feldspar (*a*)
(7)	50 N. C. feldspar (*a*) 50 talc (*e*)
(8)	50 Blue Mountain nepheline syenite (*b*) 50 talc (*e*)
(9)	75 Blue Mountain nepheline syenite (*b*) 25 talc (*e*)
(10)	94 N. C. feldspar (*a*) 3 $MgCO_3$ 3 $CaCO_3$
(11)	94 Blue Mountain nepheline syenite (*b*) 3 $MgCO_3$ 3 $CaCO_3$
(12)	90 N. C. feldspar (*a*) 10 pyrophyllite (*f*)
(13)	90 Blue Mountain nepheline syenite (*b*) 10 pyrophyllite (*f*)

off and the drafts were closed. The test pieces (four each for each run) were fired in two saggers, two of a given body in one sagger and two in the other sagger.

VI. Results

The potash feldspar (curve No. 1, Fig. 3) first started to shrink at cone 02; it has a P.C.E. of 8 to 9, and a sintering range of nine cones. Blue Mountain nephe-

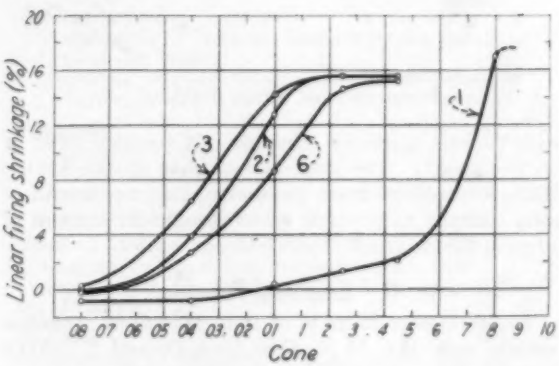

FIG. 3.—*Curve 1*, potash feldspar; *curve 2*, syenite (*b*); *curve 3*, syenite (*d*); *curve 6*, syenite (*b*) 75%, potash feldspar (*a*) 25%.

line syenite (*b*) starts to sinter at cone 08; it has a P.C.E. of 6, with a sintering range of approximately thirteen cones.

The sintering range for nepheline syenite (*d*) (curve 3, Fig. 3) is a little longer than that of the Blue Mountain nepheline syenite (curve 2).

The absorption values at cone 01 were 4.5% for nepheline syenite (*d*), 8.6% for nepheline syenite (*b*),

TABLE IV

ABSORPTION (% dry basis)

Cone No.	Body No. (1)	(2)	(3)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
08											
04		24.6	14.3	24.5	32.1	24.0	19.5	Weak	4.5	32.8	24.5
01	Weak	8.6	4.5	13.5	28.3	12.0	0	37.4	0	28.4	8.3
3[1]	33.0	0	0	0	16.9	0	0	10.3	0	22.2	0
5[1]	26.3	0	0	0	14.7			2.5		17.9	0
8	0				0					0	0

and no value was determined on the potash feldspar (*a*), owing to its fragile structure (see Table IV). Curve 6 (Fig. 3) represents the firing shrinkage of the batch, 75% nepheline syenite (*b*) and 25% potash feldspar (*a*). At cone 01, this body had an absorption of 13.5% as compared to 8.6% for body No. 2 (100% nepheline syenite (*b*)).

Consideration of the relative sintering ranges of these materials involves both the oxides comprising

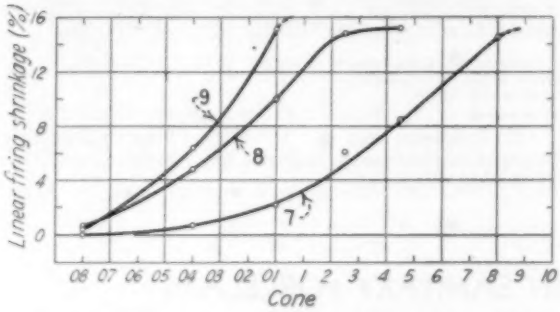

FIG. 4.—*Curve 7*, talc 50%, potash feldspar 50%; *curve 8*, talc 50%, syenite (*b*) 50%; *curve 9*, talc 25%, syenite (*b*) 75%.

these materials and their mineralogical constitution. Potash feldspar is a mineral, whereas nepheline syenite is a rock essentially composed of nepheline, soda feldspar, and potash feldspar. The thermochemical equilibrium system, Na_2O–Al_2O_3–SiO_2, offers an explanation of the wide sintering ranges of nepheline syenites. There is a eutectic between soda feldspar and nepheline which melts near 1050°C. This undoubtedly is a factor in the wide sintering ranges of nepheline syenite. This equilibrium system can be used only as an indication of the thermochemical developments transpiring in the fusion processes of nepheline syenites because nephelines and feldspars occurring in nature contain varying amounts of oxides in solid solution. The eutectic proportion is roughly 25% nepheline and 75% albite. In those nepheline syenites in which nepheline predominates, the high temperature form of nepheline is the last crystalline phase to disappear upon heating. At the same degree of fusibility as indicated by the condition at which potash feldspars and nepheline syenites, respectively, deform as pyrometric cones, the latter are the more opaque. Petrographic examination of thin sections of these materials indicates that the opaqueness of the deformed nepheline syenite cones is due largely to the presence of crystalline phases. The presence of the soda feldspar is another factor. This condition of opaqueness is more pronounced with nepheline syenites in which the mineral nepheline is the predominating constituent. Because nepheline is incompatible both with silica and with mullite (or clay), the action of the nepheline must be due both to the chemical reaction with silica of the flint and clay and to the physical solution processes as afforded by the feldspars.

The results of Geller and Creamer[1] indicate that refractoriness increases and the softening range decreases with an increase in K_2O. Nepheline syenites are higher in soda than in potash, and undoubtedly the longer sintering ranges of nepheline syenites are in part explained by this fact.

Body No. 7 (50% potash feldspar (*a*) and 50% talc) is a typical mixture used for fluxing some tile bodies. Body No. 8 is analogous to body No. 7, except that nepheline syenite replaces the potash feldspar. The firing-shrinkage curves of these two combinations are somewhat similar, except that the syenite-talc body develops at about four cones lower. At cone 3, the syenite-talc body No. 8 had 0% absorption, whereas the feldspar-talc body No. 7 had an absorption of 16.9% (Fig. 4).

Pyrophyllite is another relatively new ceramic raw material from which some fluxing action is derived in conjunction with feldspars. Body No. 12 (90% feldspar, 10% pyrophyllite) and body No. 13 (90% syenite, 10% pyrophyllite) show the action of feldspar

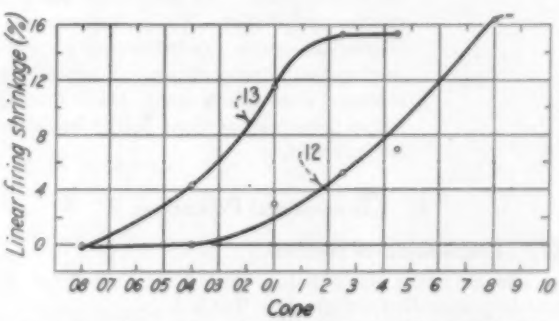

FIG. 5.—*Curve 12*, potash feldspar 90%, pyrophyllite 10%; *curve 13*, syenite (*b*) 90%, pyrophyllite 10%.

and nepheline syenite in the order given (see Fig. 5); the firing shrinkage of body No. 12 started at a lower temperature than the feldspar alone. Indications are that nepheline syenite (*b*) (body No. 13) received

[1] R. F. Geller and A. S. Creamer, "Investigation of Feldspar and Its Effect in Pottery Bodies," *Jour. Amer. Ceram. Soc.*, **14** [1] 30–71 (1931).

no fluxing impetus from the admixture of 10% pyrophyllite. At cone 01, body No. 12 (feldspar-pyrophyllite) had an absorption of 28.4% as compared to 8.3% for body No. 13.

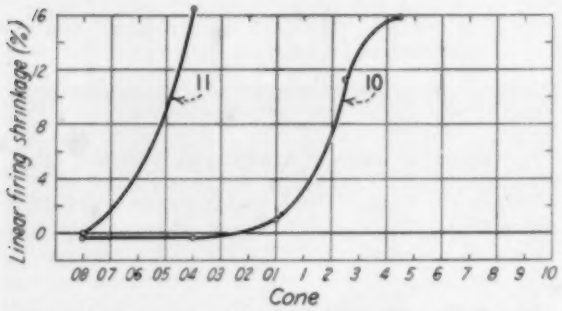

FIG. 6.—*Curve 10*, potash feldspar 94%, $MgCO_3$ 3%, $CaCO_3$ 3%; *curve 11*, syenite (*b*) 94%, $MgCO_3$ 3%, $CaCO_3$ 3%.

In a number of vitreous bodies, small percentages of auxiliary fluxes, such as whiting ($CaCO_3$) and magnesium carbonate ($MgCO_3$) are used. To determine whether these materials promote as much activity with nepheline syenite as they do with potash feldspar, bodies Nos. 10 and 11 were included in this investigation. As can be seen in Fig. 6, the addition of these carbonates either to potash feldspar (body No. 10) or nepheline syenite (*b*) (body No. 11) causes a short sintering range. Firing shrinkage curves of these two bodies are somewhat similar, but the syenite-whiting-magnesium carbonate blend is active at about 5 cones lower than the comparative potash feldspar mixture. At cone 04, body No. 11 had an absorption of 4.5%, and the value for body No. 10 was not determined because the specimen was very weak.

It has been shown in the literature that while soda feldspars start to act at an earlier temperature than potash feldspars, they are not as active in combination with whiting as potash feldspar. Schramm and Hall[4] state that this is caused by the fact that most soda feldspars already contain an appreciable amount of CaO. The Blue Mountain nepheline syenite contains only 0.27% CaO.

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Grateful acknowledgment is given to G. A. Bole and W. J. McCaughey for their helpful advice and to the American Nepheline Corp. and the Great Lakes Foundry Sand Co., who jointly subsidized this investigation.

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[4] E. Schramm and F. P. Hall, "Fluxing Effect of Feldspar in Whiteware Bodies," *Jour. Amer. Ceram. Soc.*, **19** [6] 159–68 (1936).

USE OF NEPHELINE SYENITE IN SANITARY PORCELAIN*

BY C. J. KOENIG

ABSTRACT

By introducing nepheline syenite in sanitary porcelain in reduced amounts to replace potash feldspar, a longer vitrification range is afforded which results in less warpage.

Ware fluxed with nepheline syenite has a steel-like ring, the pitch being higher than the regular ware. An electrical machine for producing pure tones was used to classify the various pitches. An oscillograph was used to determine decrement or tone decay. Nepheline syenite, ground to near pottery-grade fineness, was air-separated into coarse, medium, and fine divisions. When used in a porcelain body, the fine division afforded a longer vitrification range, lower warpage, and increased mechanical strength. The sound properties of these bodies are classified. Photomicrographs of body structures are included.

I. Experimental Procedure

(1) Preparation of Bodies

The chemical compositions and screen analyses of the fluxes studied are given in Table I.

Fifteen pounds dry weight of each body were prepared, and allowance was made for the water content of the clays. The batches were slaked in distilled water overnight in a butter-churn type blunger. Blunging was conducted for three hours (20 r.p.m.) at a specific gravity of about 1.40. The slips were passed through a 120-mesh screen, over magnets, and were partially dewatered in plaster molds to about 1.80 specific gravity. Electrolytes were added in an amount of 0.6% on the dry weight bases (15% sodium carbonate, 85% sodium silicate (N brand)). The slips were adjusted to a specific gravity of 1.80 and were blunged for an additional hour prior to casting.

The body compositions and physical properties are given in Tables II and III.

(2) Testing

In general, the methods, apparatus, and calculations given by the American Ceramic Society[1] were used to

* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 29, 1938 (White Wares Division). Received April 16, 1938.

[1] Standards Report, *Jour. Amer. Ceram. Soc.*, **11** [6] 1928.

TABLE I

CHEMICAL COMPOSITION OF VITRIFICATION AGENTS USED

Oxide	Potash feldspars		Nepheline syenites*		
	N. H. (A)	Maine (B)	Blue Mountain† (C)	Bancroft† (D)	Bancroft‡ (E)
SiO_2	68.30	71.30	59.30	48.92	50.20
Al_2O_3	17.90	16.70	24.70	31.69	30.40
Fe_2O_3	0.07	0.05	0.06	0.10	0.13
TiO_2			0.002		< 0.01
CaO	0.31	0.03	0.27	0.86	0.71
MgO			0.02	0.06	
Na_2O	2.87	3.80	9.91	13.70	12.88
K_2O	10.14	7.80	5.10	4.06	3.40
Ignition loss	0.26		0.44	0.40	0.41
Total	99.85	99.68	99.802	99.79	98.14
	Screen analysis (% residue)				
On 180-mesh	0.09	0.60	0.05	0.07	0.32
200 "	0.12	0.70	0.28	0.42	1.25
240 "	0.18	0.85	0.37	0.53	
270 "	0.86	2.30	1.58	0.95	2.70
325 "	1.14	2.47	3.90	1.88	3.50

* These deposits belong to the American Nepheline Corp. The name "Blue Mountain nepheline syenite" has been changed to "Lakefield nepheline syenite."

† Commercially available.

‡ Uniformity must be proved.

determine water of plasticity, shrinkage, and modulus of rupture.

The coefficient of thermal expansion and percentage near thermal expansion determinations were made upon fired bars with a fused quartz expansion apparatus designed by the National Bureau of Standards.[2]

The viscosity was recorded as time of flow of 250 cc. of slip from a viscosimeter (given orifice).

Sag tests were made by firing the solid cast specimens (1/2 by 2 by 8 in.) placed on supports six inches apart. The sag index of the body under fire is represented by the ratio of deflection to the span (6 in.) multiplied by 100.

(3) Firing

Aliquot portions of the bodies were fired as follows: (1) cone 7[2] (hotel china glost kiln), (2) cone 10 touch (semivitreous bisque kiln), and (3) cone 12[2] (sanitary porcelain kiln).

II. Discussion of Results

(1) Absorption

Substitution of nepheline syenites for potash feldspar in a sanitary porcelain body produced increased vitrify-

[2] Peter Hidnert and W. T. Sweeney, "Thermal Expansion of Magnesium and Some of Its Alloys," *Bur. Stand. Jour. Research*, **1** [5] 771–92 (1928); *Ceram. Abs.*, **8** [1] 65 (1929).

TABLE II

BODY COMPOSITIONS (%)

	Body No. (1)	(3)	(4)	(5)	(6)	(8)	(9)	(10)	(14)
Jernigan ball clay	15	15	15.6	15.6	15	15	15.6	15	15
Champion and Challenger ball clay	10	10	10.3	10.3	10	10	10.3	10	10
VC-1 English china clay	25	25	26	26	25	25	27	25	25
Nepheline syenite (C)	0	25	22	19	12.5	0	0	0	0
Nepheline syenite (D)	0	0	0	0	0	25	18	0	0
Nepheline syenite (E)	0	0	0	0	0	0	0	25	0
Potash feldspar (A)	25	0	0	0	12.5	0	0	0	0
Maine feldspar (B)	0	0	0	0	0	0	0	0	25
Flint	25	25	26	29	25	25	29	25	25

TABLE III

PHYSICAL PROPERTIES

	Body No. (1)	(3)	(4)	(5)	(6)	(8)	(9)	(10)	(14
	Plastic molded bars								
Water of plasticity*	21	22	21	22	20	20	19.5	22	20
Absorption*									
Cone 7[2]	4.5	1.6	2.4	2.8	3.9	0	0.5	0.3	5.9
Cone 10	0	0	0	0	0	0	0	0	0
Cone 12[2]	0	0	0	0	0	3.9	0	3.8	0
	Cast specimens								
Viscosity†	70.5	81	78	75	87	84	105	81	74
Absorption									
Cone 7[2]	8.0	3.8	4.1	7.5	5.8	0	3.2	1.9	9.8
Cone 10	0	0	0	0	0	0	0	0	0
Cone 12[2]	0	0	0	0	0	1.8	0	0.3	0
Sag index									
Cone 7[2]	2.79	3.33	3.07	2.83	3.17	2.56	2.42	3.27	2.77
Cone 10	3.67	4.12	3.11	2.98	3.50	3.48	3.34	3.50	3.42
Cone 12[2]	3.47	4.05	2.84	2.53	3.38	6.50	3.03	4.50	3.0

* Given in percentage (dry basis).

† Time in seconds for flow of 250 cc. of slip from viscosimeter (given orifice).

ing action, which differed in degree with the different syenites; the activity increased with increasing nepheline content.

Absorption values were determined on hand-molded bars and solid cast specimens. The bars had lower absorption values than the cast specimens in those cases where the bodies were approaching maturity; conversely, when a body was overfired, the hand-molded bars showed the most open structure.

Absorption values on the hand-molded bars at low fire ranged from 5.9% on body No. 14 (with Maine potash feldspar as the flux) to 0% for body No. 8, which differed from body No. 14 in that nepheline syenite (D) was substituted for the potash feldspar. Body No. 8, cast, still had 0% absorption, whereas the value for body No. 14 was 9.8%.

Eighteen per cent of nepheline syenite (D) (body No. 9) and 19% nepheline syenite (C) (body No. 5), respectively, produced more vitrifying action than 25% of either of the two potash feldspars tested (bodies Nos. 1 and 14). With nepheline syenites in reduced amounts, the bodies started to mature earlier than the standard feldspar bodies and showed no evidence of overfiring as a result of the high firing treatment. All of the bodies were completely vitrified when fired to cone 10 down in a semivitreous kiln. On the high firing schedule (cone 12^3), bodies Nos. 8 and 10 (cast specimens), which contained syenites predominated by nepheline, were the only bodies which were overfired as indicated by absorption.

(2) Shrinkage

Linear shrinkage values were determined on plastic molded bars (Table IV). These values in general were inversely related to the absorption values.

(3) Modulus of Rupture

When firing to cone 7^3, nepheline syenite fluxed ware was stronger than ware fluxed with potash feldspar (Table V).

The highest strength shown by the several bodies on the cone 7^3 firing of the hand-molded bars was 7500 lb. per sq. in. This was body No. 8, in which nepheline syenite (D) was substituted directly for potash feldspar. The parallel value for cast specimens from the same body was 8050 lb. per sq. in.; the lowest value was 3000 lb. per sq. in., which was body No. 14, one of the standard potash feldspar bodies. When firing to cone 10^6 the values, generally speaking, were in the same range.

(4) Sag Index

On the firing schedule to cone 7^3, most of the bodies fluxed with nepheline syenites showed a little more warpage than those (Nos. 1 and 14) fluxed with potash feldspar. Bodies Nos. 8 and 9 at cone 7^3 showed less warpage than the feldspar fluxed bodies.

Body No. 5, which incorporated 19% of Blue Mountain nepheline syenite (C) to replace 25% of potash feldspar, started to vitrify sooner than the feldspar fluxed bodies and warped less on the higher firing schedule (see Fig. 1).

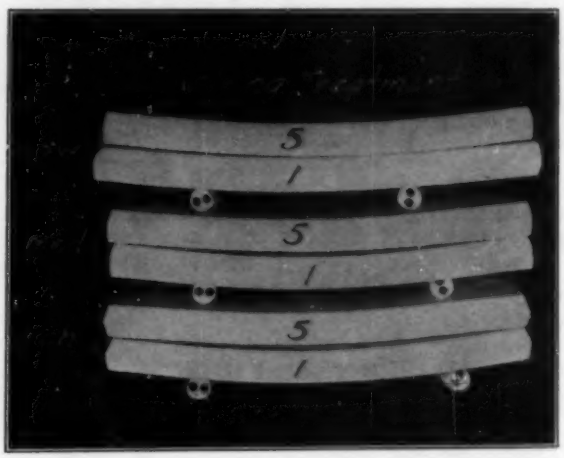

FIG. 1.

TABLE IV

PLASTIC MOLDED BARS

Shrinkage (% dry basis)

Cone No.	Body No. (1)	(3)	(4)	(5)	(6)	(8)	(9)	(10)	(14)
					Firing shrinkage				
7^3	6.8	8.6	8.1	7.9	8.3	9.0	8.1	8.2	5.4
10^6	8.6	9.0	8.9	8.7	9.3	8.0	8.0	8.4	8.0
12^3	8.4	8.6	8.4	8.7	8.8	6.8	7.5	6.9	7.8
					Total shrinkage				
7^3	10.6	12.4	11.9	11.7	12.3	12.2	11.5	12.0	8.6
10^6	12.2	12.9	12.8	12.3	13.2	11.5	11.5	12.8	12.1
12^3	12.0	12.3	12.1	12.4	12.5	9.9	10.8	10.2	11.6

With two exceptions, the warpage of the bars in the cone 12^3 (sanitary porcelain) was lower than in the cone 10 firing (semiporcelain bisque).

(5) Thermal Expansion

Nepheline syenite has a greater thermal expansion than potash feldspar. On the cone 7^3 rapid fire (Fig. 2), the composition of the binding or liquid phases is considerably nearer the initial flux composition than on the higher and longer firings; in the latter firings, more of the other body constituents have dissolved in

TABLE V

MODULUS OF RUPTURE (lb./sq. in.)

Cone No.	Body No. (1)	(3)	(4)	(5)	(6)	(8)	(9)	(10)	(14)
					Plastic molded bars				
7^3	3840	5320	5010	4910	5400	7500	5190	6470	3990
10^6	6730	6990	6510	6420	6530	4820	6750	4510	6640
12^2	7310	4670	5690	5850	5880	4045	5280	2880	7130
					Cast specimens				
7^3	4900	6080	5800	6250	5010	8050	5410	5300	3000
10^6	7100	10070	9470	10800	8830	8610	10050	8870	5930
12^2	8160	10050	8900	10360	10300	8010	8420	8300	8290

the binding phase. The thermal history bears an important relationship to this property.

When nepheline syenites are used in amounts appropriately reduced and fired as in regular practice to produce a vitreous body, the expansion curves are similar to those of a potash feldspar fluxed body (Fig. 3).

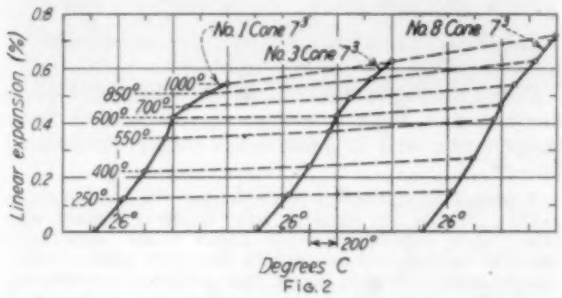

FIG. 2

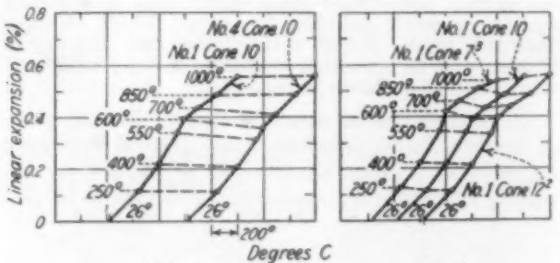

FIG. 3

FIG. 4

Figure 4 shows three expansion curves of the standard feldspar body fired at three different temperatures.

In Fig. 5, it will be noted that the bodies fired to cone 7^3 have greater expansion and more free flint present; bodies Nos. 4 and 5 have a higher initial flint content and lower nepheline syenite content than No. 3. The increased amount of undissolved flint is reflected in the curves.

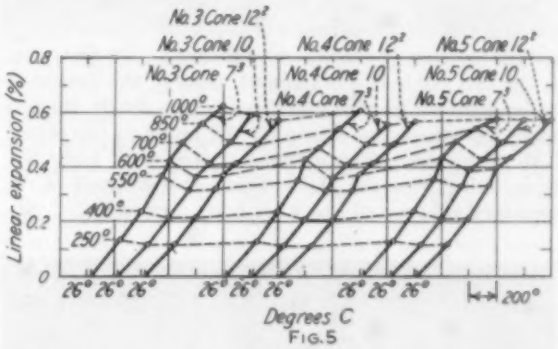

FIG. 5

Figure 6 represents the thermal expansion of body No. 6 (the flux content is equal parts of Blue Mountain nepheline syenite (C) and potash feldspar (A)). The combined influence of these fluxes on the thermal expansion is exemplified in the body fired to cone 7^3. The curve is intermediate between similar bodies respectively embodying feldspar and nepheline syenite as the flux. Differentiations are not so marked between

TABLE VI

PHYSICAL PROPERTIES OF BODIES

Cone No.	Body No. (11) 7^3	(11) 10	(11) 12^2	(12) 7^3	(12) 10	(12) 12^2	(13) 7^3	(13) 10	(13) 12^2
					Plastic molded specimens				
Water of plasticity*		19.5			21			22	
Absorption*	4.5	0	0	3.7	0	0	0.8	0	0
Linear firing shrinkage*	6.6	8.8	7.5	6.6	8.2	7.6	8.7	9.0	8.2
Total firing shrinkage*	10.4	12.2	10.9	10.4	12.6	11.0	11.9	12.1	11.3
Fired modulus†	4680	6170	5710	5870	6500	6930	5870	7300	7320
					Cast specimens				
Viscosity‡	53				73				122
Absorption*	7.6	0	0	4.1	0	0	2.8	0	0
Fired modulus*	5190	9350	8700	5300	9600	8520	5600	9800	9200
Sag index	2.94	3.83	3.69	2.83	3.68	3.43	2.62	2.77	2.73

* Given in percentage (dry basis).

† Lb./sq. in.

‡ Time in seconds for flow of 250 cc. of slip from viscosimeter (given orifice).

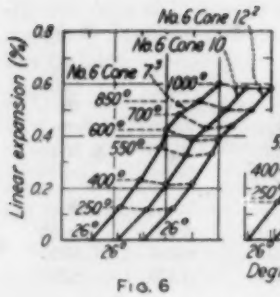

Fig. 6

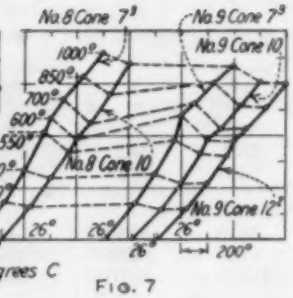

Fig. 7

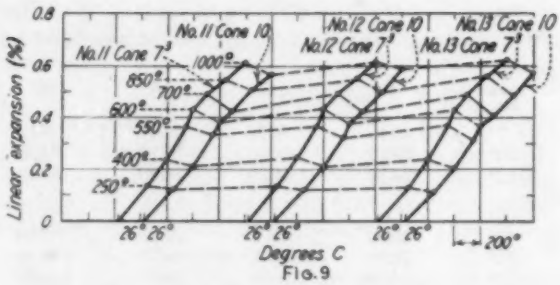

Fig. 9

body No. 6, fired to the higher cones (*i.e.*, 10 and 12²), and similar bodies, fluxed respectively with potash feldspar and Blue Mountain nepheline syenite.

Figure 7 shows the thermal expansion curves of bodies Nos. 8 and 9. These bodies contain as their vitrifying agents nepheline syenites predominating in the mineral nepheline.

Body No. 8 at cone 7³ is vitreous and body No. 10 is nearly vitreous at this temperature. These bodies contain a direct substitution of nepheline syenite (25%) for the feldspar in the standard formula. In body No. 9, the flux content was reduced to 18%, the difference being replaced by flint and clays. As a result, there is more free quartz, as shown by the hump in the curve. The pronounced drop in total expansion of body No. 9, resulting from the higher firing, is significant of the increased solution of the other body members.

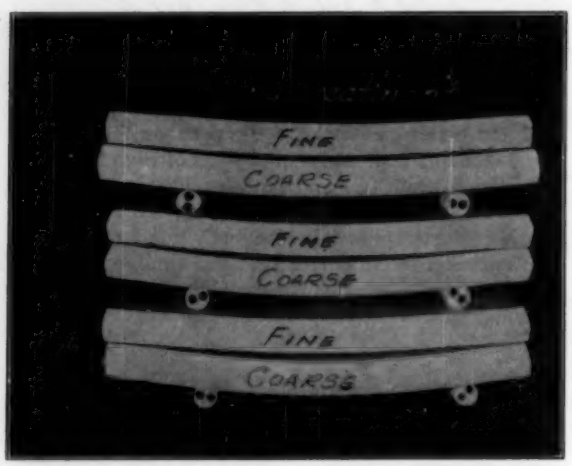

Fig. 8.

III. Influence of Grain Size on Physical Properties of Porcelain

Although grain-size studies with feldspars have been conducted, the rôle played by nepheline must be considered. A comparison of the fluxing actions of nepheline syenite and potash feldspar from the thermochemical standpoint has been given.

(1) Experimental Procedure

The formula used for this phase of the investigation is the same as body No. 4 (Table II) except for the fineness of the nepheline syenite grains,[3] which are as follows:

Body No.	Size microns
11	55 (coarse)
12	13 (medium)
13	3 (fine)

See Table VI for the physical properties of these bodies.

Figure 8 shows that when nepheline syenite is finely ground, there is less warpage, it acts at lower temperature, and it promotes a longer vitrification range.[4]

A probable explanation of the longer vitrification range is that the fine flux particles have intimate contact with other body ingredients. The liquid phase accordingly tends to be more saturated with the other phases and is more viscous. Where larger flux particles are present, the surface layers have more opportunity to approach equilibrium conditions than the centers, which are more fluid as a result. Fritz[5] reported that finer grinding of feldspar and flint resulted in increased firing range and vitrification of porcelain bodies.

Thermal expansion curves of these bodies are given in Fig. 9. There is an effect of fineness of flux particles on the relative expansion of bodies below the temperature at which the applied glazes are so viscous or rigid that they can no longer absorb contracting forces without setting up strains.[3] This is important from the glaze-fit angle. At temperatures up to 700°C, the expansion of body No. 13 (cone 10, fine flux) is lower than that of body No. 11 (cone 10, coarse flux). The latter would tend to place the glaze under more compression. The more intimate association of the finely pulverized flux particles with the other body ingredients permits the former to assimilate oxides more readily which in turn influences the glassy phase.

(2) Microscopic Structure of Bodies

Thin sections of the samples were prepared from solid cast specimens of the various bodies.

The entire series of photographs was taken at the same magnification (475 ×) for purposes of comparison.

[3] See "Fundamental Properties of Nepheline Syenite," this issue, pp. 35-38.

[4] R. F. Geller, D. N. Evans, and A. S. Creamer, "Effects of Particle Size of a Potter's 'Flint' and a Feldspar in Whiteware," *Bur. Stand. Jour. Research*, **11** [3] 327–40 (1933); *Ceram. Abs.*, **12** [12] 427 (1933).

[5] E. H. Fritz, "Present Practice and Development in the Firing of Electrical Porcelain," *Jour. Amer. Ceram. Soc.*, **20** [1] 26–30 (1937). Fritz reported that finer grinding of feldspar and flint resulted in increased firing range and vitrification of porcelain bodies.

Crossed Nicols were used to bring out the detail of the quartz grains, and a gypsum plate was used in conjunction with the crossed Nicols to provide more detail in the glassy phase. This renders the whole field red of the first order. A 3-mm. dry achromatic objective (No. 7) was used in conjunction with a 12 × periplanatic ocular.

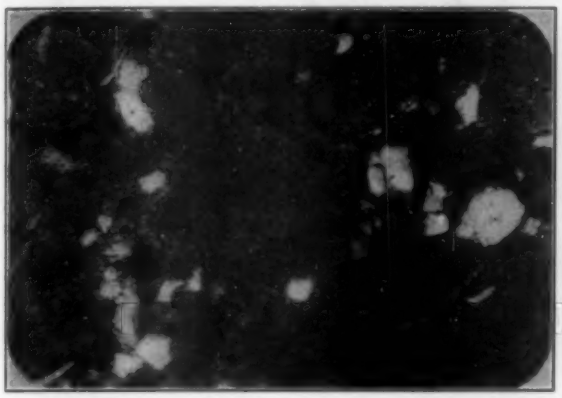

FIG. 10.—Body No. 11, cone 10, 0% absorption.

In the center of Fig. 10 (body No. 11, cone 10, 0% absorption), there is a large patch of mullite needles. These needles are well developed and are as long as any found in this investigation. Quartz solution is readily detected in this body. The average particle size of the nepheline syenite particles introduced in this body was 55 microns, which accounts for the large patches of mullite needles.

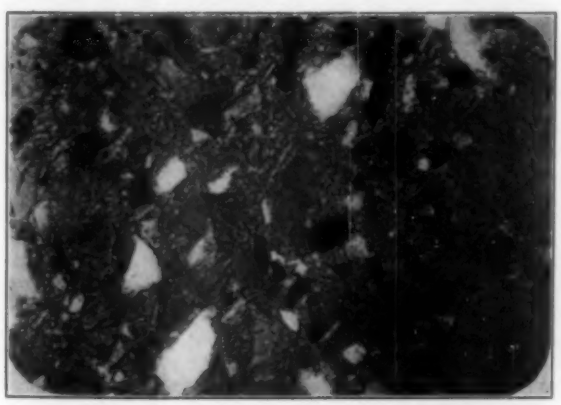

FIG. 11.—Body No. 12, cone 10, 0% absorption.

Figure 11 (body No. 12, cone 10, 0% absorption) is similar to body No. 11 except that the patches of mullite needles occurring in pseudomorphs of flux grain are not so large; the average size of the flux particles was 13 microns.

The flux particles embodied in body No. 13 (see Fig. 12) were very fine (average particle size 3 microns). A patch of mullite needles is present only occasionally, and these are small. The fine grinding of the flux has furthered a uniform distribution of the binding phase. This factor has influenced a number of the physical properties of this body. Quartz solution is in evidence.

IV. Sound Properties

For many years, the ring of ware has been used as a criterion of a well-knit product and in a general way to

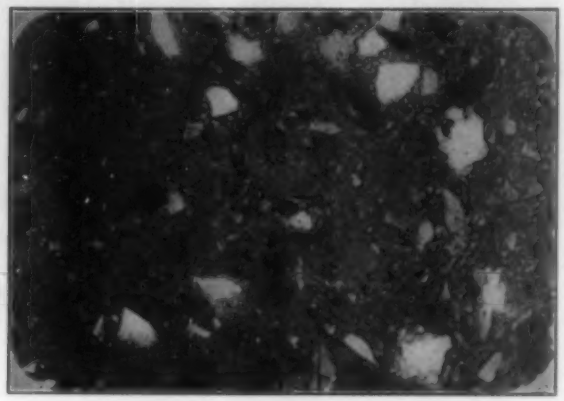

FIG. 12.—Body No. 13, cone 10, 0% absorption.

indicate the degree of vitrification. An endeavor is made here to evaluate the sound qualities of ceramic ware on a scientific basis. The idea of classifying the sound properties did not occur until the striking differences in the pitches of the various bodies had been noted. Accordingly, the sag-test specimens were used in making these tests.[6] The data and technique

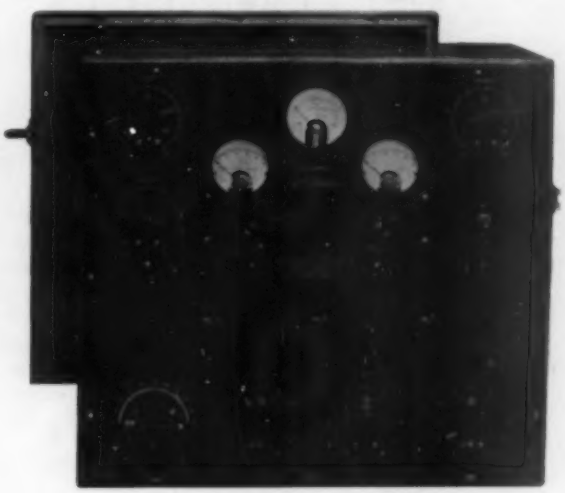

FIG. 13.

are presented as being of a pilot nature. A series of tests is being conducted to determine optimum specimen sizes and other factors which will afford precise measurement.

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[6] H. P. Knauss, Department of Physics, Ohio State University, Columbus, Ohio, collaborated in these tests.

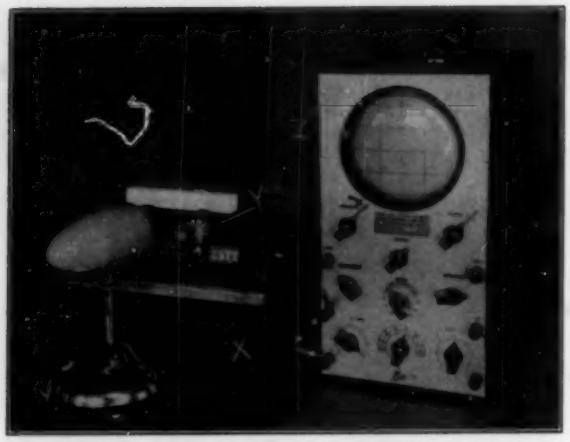

FIG. 14.—(*V*) dynamic microphone; (*Y*) solenoid; (*X*) instrument for striking specimen; (*Z*) screen of cathode ray tube.

(1) Experimental

Two qualities of the "rings" emitted by ceramic bodies were determined, namely, pitch and decrement or tone fatigue. The pitch of a sound depends on the frequency of the vibrations in the sound wave. The frequencies in cycles per second of these specimens were obtained by comparison with a calibrated electrical generator of pure tone (see Fig. 13). The limit of accuracy of the frequency determination is from 5 to 10 cycles per second.

In determining decrement or decay of tone, patterns of the sound waves were made visible by an oscillograph and were photographed (see Fig. 14). The sweep frequency was matched against the frequency of the specimen ring.

Louder tones produce greater amplitude of the waves. If the intensity of the tone decreases rapidly, successive traces are distinct from each other because of decreasing amplitude. A still photograph serves to record these successive traces. A greater distance between successive traces indicates a more rapid decay of tone. No quantitative investigation of the decay has yet been made, but qualitative comparisons can be made directly from the photographs and can be correlated with the compositions and firing of the specimens.

All of the test bodies were made from the same size mold, but they differed somewhat in dimensions after firing. No correction has been made for the effect of size difference on the frequency of the specimens. Thus the frequency values bear relationship to the nature and amount of flux. The difference in dimensions is negligible in the bodies which were vitreous.

(2) Results

The frequencies of the bodies are given in Figs. 15, 16, and 17. The relative decay values are illustrated in Fig. 18.

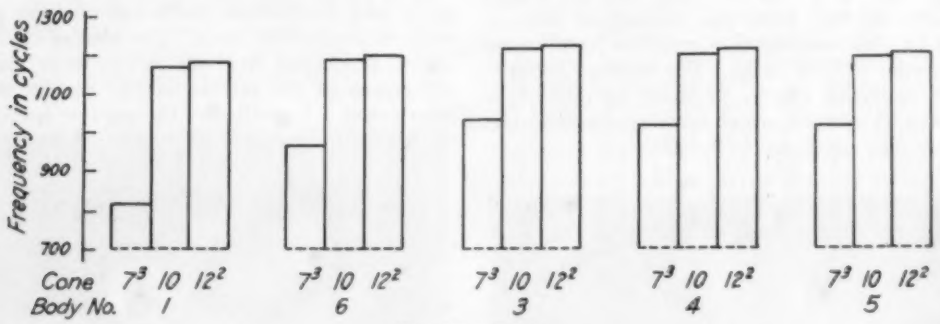

FIG. 15.—Pitch.

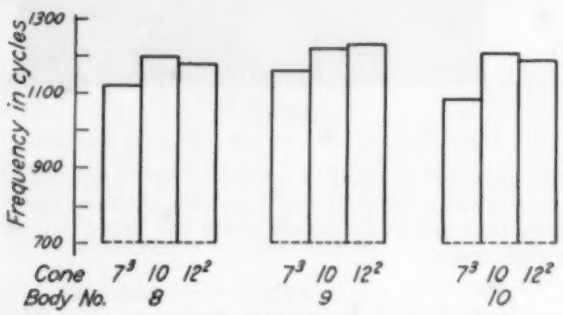

FIG. 16.—Pitch.

(3) Discussion of Results

The regular potash feldspar fluxed body No. 1, when fired to cone 7^3, had the lowest pitch. When this body was fired to cone 10, a decided increase in pitch resulted. Firing to cone 12^3 raised the pitch of the body only slightly over that obtained by firing to cone 10. Substitution of Blue Mountain nepheline syenite for potash feldspar resulted in higher pitches. The differences between these bodies fired to cone 7^3 were especially marked. This is attributed both to the nature of the fluxes and to the degree of absorption. Nepheline syenite exerts more action than potash feldspar at this temperature. When these bodies were fired to cones 10 and 12^2, respectively, the bodies fluxed with nepheline syenite had a higher tone than the potash feldspar fluxed bodies. This is attributed to the nature of the flux, inasmuch as all these bodies showed 0% absorption. The highest frequency of the potash feldspar fluxed bodies was 1185 cycles per second, and the highest frequency of the syenite fluxed bodies was 1230 cycles. The difference is readily distinguished.

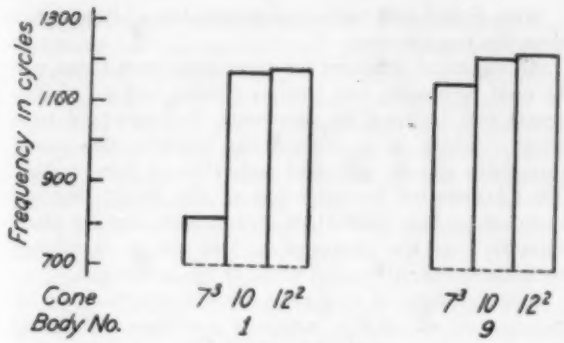

FIG. 17.—Pitch.

Body No. 6, which contained equal parts of potash feldspar and nepheline syenite as the flux, emitted tones intermediate in pitch between corresponding bodies fluxed respectively with nepheline syenite and potash feldspar.

The flux content of body No. 5 consisted of 19% Blue Mountain nepheline syenite. When fired to cone 7³, this body had about the same degree of absorption as body No. 1 (25% potash feldspar) when fired to the same cone. The latter body, however, had a considerably lower pitch than the former. This clearly shows the influence of the binding phase on the ring qualities of ceramic bodies.

Body No. 8 (flux content 25% nepheline syenite) was vitreous at cone 7³. The frequency was 1120 cycles per second. The same body fired to cone 10 had a frequency of 1200 cycles. The body was overfired at cone 12³. This overfiring was reflected in the reduced pitch. When 18% of the same nepheline syenite was used instead of 25%, no overfiring occurred (body No. 9, cone 12³); the pitch in this case increased. Body No. 10 was similar to body No. 8; overfiring and reduced pitch resulted when the body was fired to cone 12³.

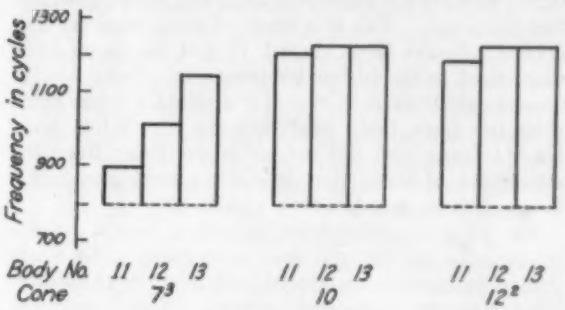

FIG. 19.—Pitch.

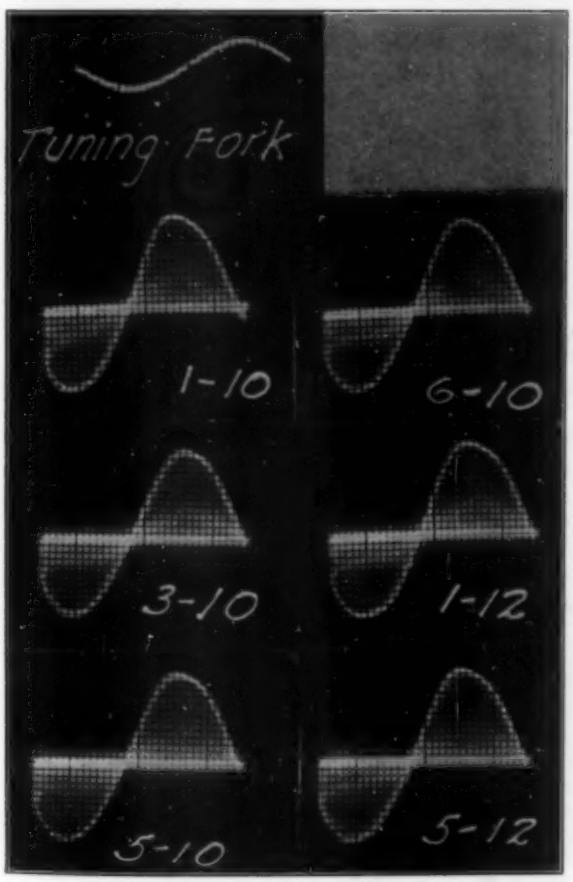

FIG. 18.—Tone decay.

(4) Decrement

The following specimens are listed in the relative order in which they dissipate energy when vibrating.

	Tuning fork		
	Body	Cone No.	Flux content (%)
Longest ring ↑	1	10	25.0 potash feldspar (A)
	5	10	19.0 nepheline syenite (C)
	6	10	12.5 potash feldspar (A) 12.5 nepheline syenite (C)
	1	12³	25.0 potash feldspar (A)
	5	12³	19.0 nepheline syenite (C)
	3	10	25.0 nepheline syenite (C)

There is an interesting relationship between the decay of vibrations and the physical properties of these bodies. The ring of a tuning fork is sustained much longer than that of ceramic bodies. Patterns of the sound waves are given in Fig. 18.

Body No. 6 (cone 10) has a decay intermediate between that of body No. 1 (cone 10) and body No. 3 (cone 10). Its flux content comprised equal parts of the fluxes used respectively in bodies Nos. 1 and 3. When the Blue Mountain nepheline syenite was introduced in reduced amounts (body No. 5, 19% replacing 25% potash feldspar), the decay was nearly the same as that of the basic feldspar body. These are the proportions in which substitution of syenite (C) for feldspar (A) is recommended. Bodies Nos. 1 and 5, fired to cone 10, had a longer ring than when fired to cone 12³, and both were vitreous when fired to cone 10. Although they showed no evidence of overfiring when fired to cone 12³, it is possible that the optimum firing

conditions had been exceeded; this observation, however, is based only on sound evidence.

The influence of grain size of nepheline syenite on the ring imparted is illustrated in Fig. 19. This influence of the fineness of grind on pitch is more pronounced when these bodies were fired to cone 7[3] than when they were fired harder. The frequency in cycles per second emitted from the bodies fired to cone 7[3] ranged from 900 for body No. 11 (7.6% absorption, coarse flux particles) to 1145 for body No. 13 (2.8% absorption, fine flux particles). This is a range of more than one-half octave. Bodies Nos. 12 and 13 had the same pitch when fired to the higher temperatures. Body No. 11 (coarse grind) fired to cone 12[2] emitted a lower pitch than the same body fired to cone 10. While body No. 11 (cone 12[2]) did not show overfiring from the standpoint of absorption, it did sag more and had a lower pitch than bodies Nos. 12 and 13.

The pitch of these bodies appears to bear a definite relationship to the physical properties. The finely ground flux particles produced a relatively more uniform bond than the coarse flux particles. This is reflected in the relative pitches.

V. General Conclusions

Results obtained using nepheline syenite in sanitary porcelain are promising. By introducing nepheline syenite in reduced amounts to replace potash feldspar, a longer vitrification range is afforded which results in lower warpage. The mechanical strength and thermal expansion of such bodies compare favorably with those using potash feldspar as the flux.

Ware fluxed with nepheline syenite has a pitch higher than the regular ware.

An electrical machine for producing pure tones can be used to classify the various pitches and an oscillograph can be used to determine decrement or tone decay. There is a relationship between the sound properties and the physical properties of these bodies. No quantitative investigation of the decay has yet been made, but qualitative comparisons can be made directly from the photographs and can be correlated with the composition and firing of the specimens.

Fine grinding of nepheline syenite lowers the temperature at which it is active in porcelain bodies and provides a longer maturing range. This is reflected in the pitch of the ware. The warpage is decreased and the mechanical strength increased.

Porcelains containing relatively coarse particles of nepheline syenite have large patches of mullite needles occurring in the pseudomorphs of flux grains. When nepheline syenite is introduced in a very fine state, the mullite development is apparent only as an occasional minute patch.

Acknowledgment

Appreciation is expressed to G. A. Bole and J. R. Beam for their helpful suggestions and to the several companies who fired the specimens and supplied samples. This study was jointly sponsored by The American Nepheline Corp., Rochester, N. Y., and The Great Lakes Foundry Sand Co., Detroit, Mich.

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ABSORPTION OF MAGNESIA BY CHROMITE SPINEL*

By L. J. Trostel

Abstract

The expansion of chrome ore-magnesite mixtures is attributed to the solid solution of magnesia in the spinel component of the ore. This conclusion is substantiated by measurements of the density, index of refraction, and lattice width, before and after exposure to magnesia.

I. Introduction

One of the improvements made in chrome refractories in recent years has been gained by better control of the firing shrinkage, characteristic of the ores used. Several commercial brick now produced contain a certain amount of dead-burned magnesite, which is known to correct partially the shrinkage. The reasons, however, for this improvement in shrinkage have not been fully understood. Seil[1] has pointed out that brick in service are made more volume-stable by magnesia additions, owing to the formation of refractory forsterite ($2MgO \cdot SiO_2$) from the lower melting talc and serpentine impurities associated with the spinel in the ore. Chesters and Rees,[2] on the other hand, noting the compensation in the firing shrinkage caused by the addition of magnesite to chrome, have offered the explanation that a compound, presumably chrome spinel ($MgO \cdot Cr_2O_3$), was formed. Evidences of this expansion were also shown in the work of Lynam and Rees,[3] who worked with mixtures of Rhodesian chromite and Grecian magnesite. Chesters

* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 30, 1938 (Refractories Division). Received April 6, 1938.

[1] G. E. Seil, "Petrography and Heat Treatment of Chromite Refractories," *Penn. State Coll. Mineral Ind. Expt. Sta. Bull.*, No. 14, pp. 40–56 (1934); *Ceram. Abs.*, **15** [1] 23 (1936).

[2] J. H. Chesters and W. J. Rees, "High-Temperature Tensile Tests on Refractories," *Refrac. Jour.*, **7** [11] 475–79 (1931); *Ceram. Abs.*, **11** [2] 110 (1932).

[3] T. R. Lynam and W. J. Rees, "Mixtures of Chromite and Grecian Magnesite, I," *Bull. Brit. Refrac. Research Assn.*, No. 29 (March, 1933); reprinted in *Trans. Ceram. Soc.* [Eng.], **36** [3] 137–51 (1936–37); *Ceram. Abs.*, **16** [10] 304 (1937).

and Parmelee,[4] in explaining the expansion of their mixtures of chrome ore and magnesite, apparently abandoned the idea of the formation of a modified chrome spinel and decided that the formation of the forsterite found in their mixtures was accompanied by an expansion which forced apart the grains of chromite, thus preventing the natural shrinkage due to melting of the associated serpentine.

It has been found, however, that practically silica-free mixes of chromite and magnesia, in which little forsterite could form, show a permanent expansion on heating; studies of these mixtures, described in this paper, indicate that spinel from chrome ore absorbs magnesia as a solid solution. The benefits, therefore, to be derived by the addition of dead-burned magnesite to chrome brick may be due to two effects, *viz.*, (1) the formation of refractory forsterite from the gangue minerals and (2) sufficient permanent expansion of the main spinel component to correct part of the shrinkage.

II. Preparation of Silica-Free Spinel from Chrome Ore

Examination with the microscope shows that practically all chrome ores are composed of two components. The major mass is a mixture of several spinels, and the remainder consists of 10 to 20% of gangue minerals, chiefly various magnesium silicates. The latter are present as thick veins as well as extremely thin films deposited between the spinel crystals, indicating that fine grinding is necessary to free the latter from the silicates. To make silica-free spinel for subsequent studies, samples of both African and Cuban ores were ground to 200-mesh and then were fluxed with about an equal weight of sodium carbonate. Both the spinel and the silicates are soluble in molten sodium carbonate, but the former dissolves with more difficulty. Fluxing about one hour was found sufficient to remove 80 to 90% of the silica without dissolving an excessive amount of the main mass of spinel. Some erosion of the grains of the latter took place, but this was desirable inasmuch as it produces cleaner surfaces on the crystals.

The effectiveness of the fluxing treatment in lowering the silica content of the ores is shown in the following data:

	African ore		Cuban ore	
	As received	Purified	As received	Purified
SiO_2 (%)	4.06	0.40	3.86	0.68

III. Expansion of Spinel-Magnesia Mixtures

Permanent expansion of chrome brick, containing magnesite, has been noted in commercial kilns fired to about cone 18 and sometimes a little lower. The experimental brick of Lynam and Rees showed expansion not only at cone 18, but also at cone 26, equivalent on the American cone scale to approximately 1490° and 1595°C, respectively. Chesters and Parmelee showed no expansion on their small laboratory specimens above 1500°C, probably because the temperatures were not carried any higher. It was felt, accordingly, that measurements should be made not only to demonstrate that the presence of magnesium silicates was not required to produce the expansion, but also as a guide in subsequent heating tests to define the optimum temperature limits causing expansion.

Two types of ores were chosen for study representing extremes in chemical constitution, *viz.*, African, of high chromic oxide and low alumina content, and Cuban, of low chromic oxide and high alumina content.

The silica-free ores, all ground to pass 200-mesh, were mixed with 10% and 20% of high-purity, electrically fused magnesite (silica content, 0.20%) and were molded into small disks about 0.5 inch in diameter. Control mixes of both ores, containing no magnesite, were also made up. Measurements were made with a micrometer to 0.005 mm. on the disks, before and after heating, in a series of draw trials conducted at 900°, 1200°, 1500°, and 1600°C, and the net linear change was calculated. Heating was conducted in the normal atmosphere of a platinum-wound tube furnace. The specimens were held for 6 hours at the various temperatures chosen and were allowed to cool slowly in the furnace. All mixes without magnesite showed shrinkage.

Data indicating that expansion is characteristic of all mixes containing magnesite are shown in Table I. These data are also plotted in Fig. 1.

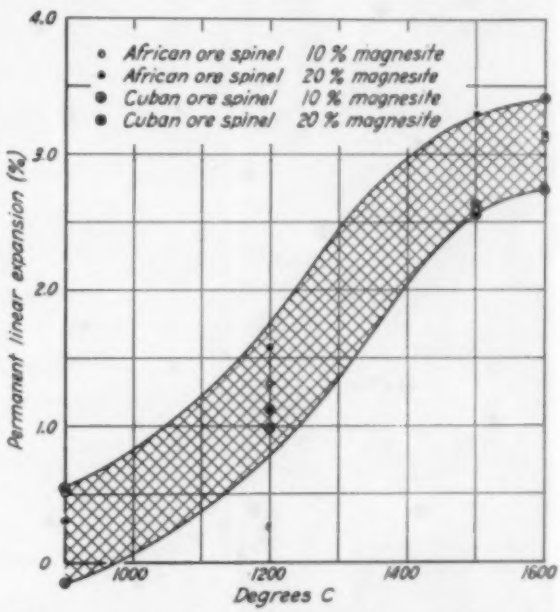

FIG. 1.—Permanent linear expansion of draw-trial specimens.

It will be noted from Fig. 1 that all expansion values may readily be grouped into a curved band which rises rapidly with temperature up to 1500°, after which the curve perceptibly flattens out. The expansion apparently is a phenomenon which is nearly at its maximum at 1500°C, and this temperature was accordingly chosen for subsequent heating tests.

[4] J. H. Chesters and C. W. Parmelee, "Reaction-Expansion Measurements on Chromite and Allied Spinels," *Jour. Amer. Ceram. Soc.*, **18** [3] 94–100 (1935).

In general, the 20% magnesia mixtures define the upper limits of the expansion band, but in some instances this concentration is not so effective as 10%. Apparently doubling the concentration of magnesia does not double the expansion. This would indicate that most of the effect is due to the lower concentration, and 20% constitutes an excess. It is not possible to conclude that magnesia affects one spinel more than the other, although the curves indicate that African ore spinel is more affected than Cuban, because the order has been reversed in other expansion tests. In fact, the particular values of the expansion are not considered to be as significant as the trend of the expansion because the values are dependent upon the fineness of the powders used, the homogeneity of mixing the two materials, the time and uniformity of heating, as well as the porosity of the test pieces before heating.

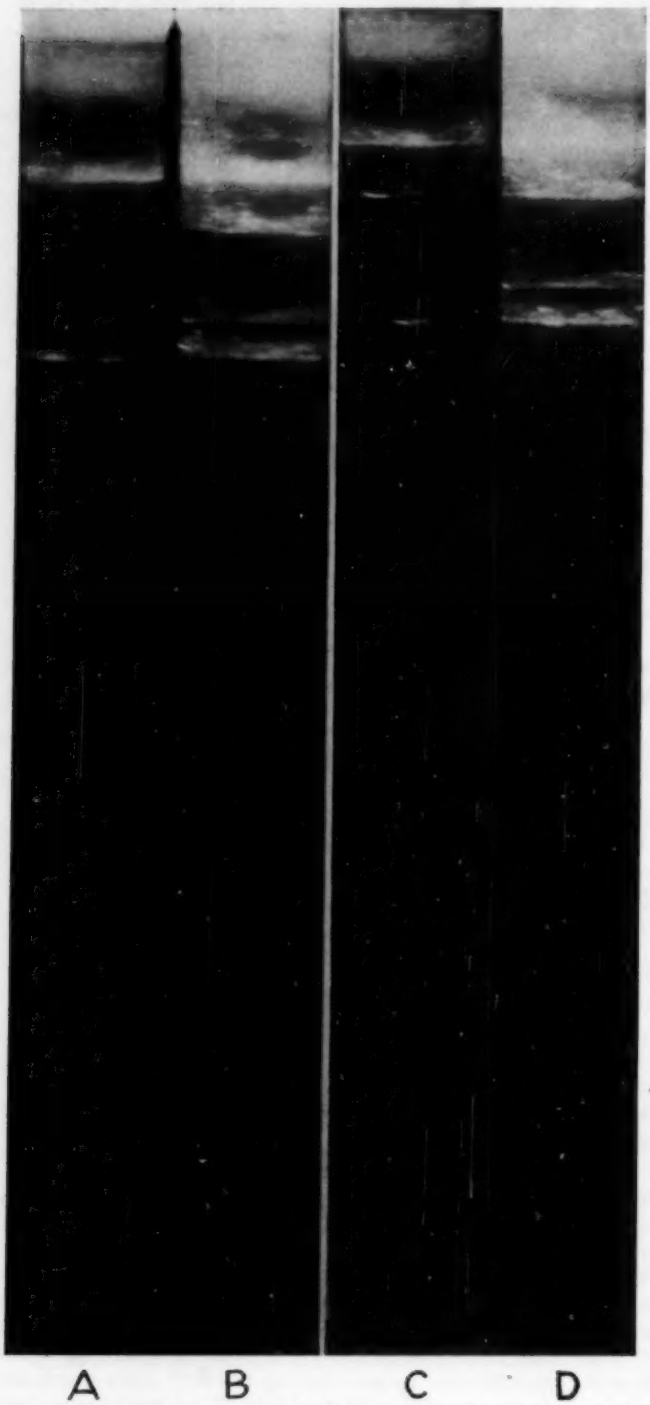

FIG. 2.—Powder X-ray diffraction spectra: (*A*) spinel from Cuban chromite before heating; (*B*) spinel from Cuban chromite after heating with magnesia; (*C*) spinel from African chromite before heating; and (*D*) spinel from African chromite after heating with magnesia.

IV. Estimation of Magnesia Absorbed by the Spinel

The foregoing data do not indicate with certainty the amount of magnesite causing the expansion phenomena, although previous investigators have shown that mixtures of chromite with 10% and 20% of magnesia were effective. Chesters and Parmelee decided that only 10% of magnesia was required if it was finely ground.

Carefully weighed batches of the 200-mesh silica-free spinel were accordingly mixed with 16% of precipitated magnesia (which, based on the expansion data, would probably be an excess), wrapped in platinum foil, and then heated for 6 hours at 1500°C in the furnace used in these tests. After cooling, the sintered mixes were reground to an impalpable powder and extracted with Lows' reagent (a solution of 200 grams ammonium chloride in 500 cc. ammonium hydroxide (sp. gr. 0.9) and 750 cc. water) to remove free magnesia. After the excess magnesia was removed, the weight of the remaining portion of the batch was determined and was compared with the original weight of the spinel used.

The weight changes of the spinel fractions (after removal of excess magnesia) show a gain of 7.35% for the African ore mix and 8.41% for the Cuban ore mix. The chemical analyses in Table II show that the gain in magnesia amounts to 7.64% and 8.86% for the African and Cuban ore mixes, respectively, and check closely the actual percentage gain in weight of the spinel fraction of the batch.

V. Character of the Phenomena

The expansion data suggest that magnesia has been absorbed into the spinel. This should also be evidenced by a lowering of the true density (d) and index of refraction (n) of the spinel with the excess magnesia removed. The extent of this drop is shown in the data in Table III. In making both measurements, spinel without magnesia was heated to 1500°C for 6 hours and was compared with the mixes

containing magnesia which had been heated similarly.

The calculated density values after exposure to magnesia are 4.35 and 4.14, respectively, for the African and Cuban ore mixtures, assuming periclase to be 3.65, although the actual lowering is appreciably greater. This suggests some opening up of the spinel structure.

TABLE I

PERMANENT LINEAR EXPANSION OF DRAW-TRIAL SPECIMENS

No.	Mix constituents	(%)	Permanent linear expansion (%) 900 °C	1200 °C	1500 °C	1600 °C
1	African spinel	90	0.52	1.32	2.58	3.14
	Magnesite	10				
2	African spinel	80	0.35	1.59	3.28	3.15
	Magnesite	20				
3	Cuban spinel	90	0.24*	0.99	2.65	2.72
	Magnesite	10				
4	Cuban spinel	80	0.54	1.13	2.56	3.40
	Magnesite	20				

* Shrinkage instead of expansion; the specimens were poorly bonded at 900°, and measurements are not so accurate as on specimens heated to the higher temperatures.

The decrease in density of the spinel, if caused by magnesia absorption in the lattice, would be accompanied by a decrease in the index of refraction. The determinations of the indices did not permit the use of the ordinary immersion oils because of the high values of the spinels. H. F. McMurdie of the National Bureau of Standards kindly consented to try the rather difficult technique of immersion of the powders in sulfur-

TABLE II

ANALYSES OF SILICA-FREE SPINEL MIXES

	African ore mixes: Before heating (100% spinel) (%)	African ore mixes: After heating (spinel + MgO) (%)	Cuban ore mixes: Before heating (100% spinel) (%)	Cuban ore mixes: After heating (spinel + MgO) (%)
SiO_2	0.40	0.38	0.68	0.48
FeO	11.50	11.17	13.94	12.49
Al_2O_3	13.62	12.84	31.06	28.81
Cr_2O_3	59.40	52.89	39.77	34.81
MgO (by difference)	15.08	22.72	14.55	23.41

selenium and in piperine and iodide melts, the indices of which had been previously established by the minimum deviation method. The values were then rechecked with immersion media composed of phosphorus, methyleneiodide, and sulfur. This mean index of refraction was lower, by a value of 0.05, for both spinel mixtures containing magnesia. Individual grains in all samples showed some variation from the mean. This was more pronounced in the samples which contained magnesia, probably owing to slightly varying degrees of magnesia absorption. The values found for the indices of refraction shown in Table III are considered to be correct to ±0.01. Another change shown by examination under the microscope was a deepening of the natural crimson color of the spinels which had been heated in the presence of magnesia. This was more pronounced in the case of the spinel from the high alumina Cuban ore.

TABLE III

d AND *n* VALUES OF SILICA-FREE SPINEL MIXES

Constant	African ore spinel: 100% spinel	African ore spinel: Spinel + MgO	Cuban ore spinel: 100% spinel	Cuban ore spinel: Spinel + MgO
d	4.41	4.23	4.18	4.02
n	2.01	1.96	1.98	1.93

X-ray patterns of the four mixes (Table III) should be of considerable value to establish the accuracy of the deductions made by the other measurements described. Diffraction spectrographs of the four powdered samples (Fig. 2) were made by J. J. B. Rutherford of the United States Steel Corporation Research Laboratory. A molybdenum target tube was used with the film at 114.6 cm. from the specimens. The powders were mounted in cellulose acetate on the edge of a card.

The patterns of the two original spinels (before exposure to magnesia) indicate similar grain size and are almost identical in the position and intensity of the lines, showing that they are of similar structure. The African spinel, however, shows a slightly larger spacing than the Cuban spinel. The difference appears to be an enlargement of the lattice as a whole and not a change in one or two directions only.

The lattice of each spinel when mixed with magnesia is slightly larger than that of the original spinel alone, and the difference is an overall increase in dimensions. There is no change in the original patterns of either of the two spinels after exposure to magnesia, which indicates that the absorbed magnesia has gone into solid solution and is not present as a separate phase. It is still possible, of course, that 2 or 3% of the original 8% of magnesia added is not in solid solution, but this does not show in the X-ray picture. An amount as large as 8%, however, would show in the picture if it were all free.

The change in dimensions of the lattice of both original spinels is consistent with the data on refractive index of the four specimens examined.

VI. Discussion

The various data of this paper indicate that the spinel from chrome ore is capable of absorbing magnesia as a solid solution resulting in expansion, although certain investigators[4] have attributed the expansion to other causes. Apparently other refractory oxides react with chrome ore spinel similarly to magnesia. Chesters and Parmelee proved, for example, that the addition of 20% of 250-mesh alumina also caused expansion, evident as low as 1275°C. These authors offered no explanation for the mechanism of this expansion. It has been established, however, by Tone[5] that alumina forms solid solutions with spinel from chrome ore.

This absorption of MgO by spinel from chrome ore conforms with the general property of the spinel group to form solid solutions with refractory oxides. Rankin

[5] F. J. Tone, "Quest for Hard Materials," *Ind. Eng. Chem.*, **30** [2] 232–42 (1938).

and Merwin[6] have shown that $MgO \cdot Al_2O_3$ forms solid solution with alpha-Al_2O_3, while Fisk and McCaughey[7] showed that this same spinel forms an almost complete series with Fe_3O_4. A regular increase in the lattice dimension, *i.e.*, expansion of the spinel, was also found as the amount of Fe_3O_4 increased.

These authors, as well as Roberts and Merwin,[8] have also pointed out that another spinel, $MgO \cdot Fe_2O_3$, may form solid solutions with MgO or Fe_3O_4. In fact, the ability of the spinels to absorb other refractory oxides is so well established that the occurrence of a spinel with the RO to R_2O_3 ratio exactly 1 to 1 is probably only an accident of nature. Parmelee and Ally[9] found all their chrome ore spinels unbalanced, and after MgO absorption a similar condition was found by the writer. Both of the purified spinels (used in these tests), before exposure to MgO, contained RO to R_2O_3 in nearly a 1 to 1 ratio, but after the absorption of MgO the RO to R_2O_3 ratio had changed to 1.48 to 1 and 1.52 to 1, respectively, for the Cuban and African ore spinels.

An explanation of the fact that the solid solution in these tests contained only 8% MgO is suggested from the work of Fisk and McCaughey[7] on the system $MgO \cdot Al_2O_3$–Fe_3O_4. They found that the spinel was capable of retaining only 50% of its absorbed Fe_3O_4 at room temperature. The analogous conclusion to be drawn on mixtures used by the writer is that chrome ore spinel may also be capable of absorbing considerably more MgO than 8%, but the solid solution unmixes as the temperature slowly falls, and only 8% is retained at the room temperatures used in these tests.

It would have been interesting to determine, from quenched mixes, whether or not the chrome ore spinel actually forms a continuous series of solid solutions with MgO at high temperatures. This, however, was not done because, at the present time, additions of magnesite beyond 25% are not feasible for commercial reasons, and furthermore the data indicate that only 8% would be retained by the spinel at the end of the cooling cycle, which is part of the history of all refractories, both in manufacture and usage.

Acknowledgments

The author wishes to express his appreciation to R. B. Sosman and Herbert Insley for their advice and kindness in making the arrangements for the X-ray and index of refraction measurements reported in this paper.

General Refractories Company
Baltimore, Maryland

[6] G. A. Rankin and H. E. Merwin, "The Ternary System CaO–Al_2O_3–MgO," *Jour. Amer. Chem. Soc.*, **38**, 571 (1916).

[7] H. G. Fisk and W. J. McCaughey, "Equilibrium Studies in Systems Containing Magnesium Oxide, Iron Oxide, and Magnesium Aluminate," *Ohio State Univ. Eng. Expt. Sta. Bull.*, No. 70, pp. 1–44 (1932); *Ceram. Abs.*, **12** [3] 128 (1933).

[8] H. S. Roberts and H. E. Merwin, "System MgO–FeO–Fe_2O_3 in Air at One Atmosphere," *Amer. Jour. Sci.*, **21** [122] 145–57 (1931); *Ceram. Abs.*, **11** [3] 202 (1932).

[9] C. W. Parmelee and Abde Ally, "Some Properties of Chrome Spinel," *Jour. Amer. Ceram. Soc.*, **15** [4] 213–25 (1935).

USE OF LITHIUM CARBONATE IN RAW ALKALINE GLAZES*

By Florence Wood Richardson

Abstract

The results of using lithium carbonate to replace the more soluble alkalis and their frits in glazes fired between cones 07 and 05 are discussed. Owing to its unusual fluxing properties, the use of from 9 to 12% lithium carbonate permits a marked increase in the amounts of alumina, calcium, and silica which may be used, resulting in a more stable glaze, with sufficient alkalinity to produce vivid copper blues and other typically alkaline colors.

I. Introduction

The oldest glazes known are those found in Egypt on small objects which were made before the beginnings of written history. They have the clear blue colors which are characteristic of copper in alkaline glazes. Copper blues and the other rich colors obtainable only in alkaline glazes have since inspired potters of many periods and peoples. The Egyptians, the Chinese, and the Persians, especially, are famed for the magnificent colors and textures of their alkaline glazes as well as for the remarkable skill with which they controlled this difficult medium. Glorious as the examples of these glazes in our museums and collections unquestionably are, there are few of them which do not betray to the practiced eye of the potter some traces of the difficulties which underlie the use of this type of glaze at the present time. Nearly all show some sign of crazing, efflorescence, scumming, excessive fluidity, or lack of durability, even when highly siliceous bodies and unusual methods of firing were used. These difficulties seem inherent in the materials necessary to produce the desired colors and have practically limited the modern use of these glazes to studio potters.

The term, alkaline glaze, is used by studio potters to denote that type of glaze in which copper produces a bright blue; manganese, an egg-plant purple, or auber-

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This paper is a brief summary of experimental work on the use of lithium carbonate in raw alkaline glazes which has been carried on for more than two years, under the direct supervision of Arthur E. Baggs and Edgar Littlefield of Ohio State University; the subject is covered in a more comprehensive manner by a thesis submitted by the writer in partial fulfillment of the requirements for a Master's degree in fine arts.

gine; uranium, a canary yellow; and chromium, lemon-yellow or yellow-green. To obtain these characteristic colors, the glaze must be essentially an alkaline silicate, that is, it must contain an unusually high percentage of the alkalis, soda and potash, with small amounts of alumina, lead, and other normal glaze materials.

Because all the simple compounds of both soda and potash as well as the pure alkaline silicates are highly soluble in water and because the insoluble compounds are high in alumina and other materials, alkaline glazes are most commonly made by fusing the soluble alkalis and silica with one or more insoluble materials. The resulting glass or frit is then ground and used alone or with other materials as a fritted glaze. Raw alkaline glazes are those in which similar materials are ground and used with no preliminary treatment.

The raw glazes are simple to prepare, but the highly soluble character of the chief ingredients makes it difficult to use them with predictable results. Because glazes are ground in water, some of the soluble material may be lost in preparation. Furthermore, on applying the glaze to ware, the dissolved constituents may be concentrated on the surface of the drying glaze where it may form scums in firing. When used on porous ware, part of the dissolved material is often carried into the body of the piece. There it reacts with the body components in firing to form a distinct layer which, with the glaze, may break away from the body. Thus, seemingly slight differences in the preparation and application of a given glaze may decidedly change its composition and, therefore, its appearance after firing. An added fault is that upon aging, these glazes may become either gummy or hard and crystalline and therefore must be used soon after grinding.

Fritted glazes, though they are seldom entirely insoluble, are easier to use and less prone to show faults caused by soluble materials. Obviously, it is difficult to prepare frits in small potteries and it is certainly not altogether satisfactory to use commercially prepared frits of which the compositions are unknown.

When alkaline glazes are also mat glazes they are peculiarly sensitive to slight variations in temperature, rate of firing, and kiln atmosphere, and are more likely to show scum, efflorescence and grainy crystals than are the clear, glassy glazes. Such materials, as alumina, titanium, and zirconium, which are commonly used in other types of glazes to promote opacity and mat textures, are detrimental to characteristic alkaline colors. On the other hand, the materials, which seem most favorable for the development of these qualities in this type of glaze with the least effect on their colors, are bone ash and cryolite, while the reactions in a complex glaze mixture of the phosphates and fluorides of these materials are as yet little understood.

Finally, while alkaline glazes are not commonly seen uncrazed either in ancient or modern pottery, they may, if used on bodies which are very high in silica, remain uncrazed and remarkably durable for long periods.

While using various alkaline glazes on high flint bodies in the Ceramic Art Department at the Ohio State University, the writer became interested in the possibility of substituting some compound of lithium for the soluble compounds of sodium and potassium. This seemed to be a logical possibility because of the position of lithium in the Periodic Table, which shows it to be the most powerful alkali and therefore an active flux, and because of its occurrence in such natural mineral compounds as petalite, spodumene, amblygonite, and lepidolite. Lithium seemed especially desirable because it differs from the other members of the alkaline metals group in that several of its simple compounds, such as the carbonates, phosphates, and fluorides, are but slightly soluble in water. The carbonate was chosen for experiment because of its availability, its simple form, and its sparing solubility, which is only 1.3 parts in 100 parts of water at room temperature.

The aim of the work was the development of a practical, dependable glaze maturing at cone 06 which would retain the deep rich colors of true alkaline glazes and possess a smooth, satiny surface, preferably dull or mat. This investigation was restricted to glazes which contained no frits and no soluble materials other than the sparingly soluble lithium carbonate.

II. Technical Investigations

The first experimental glazes were based upon the formula for a rich blue, mat glaze, BC2E, developed by Mr. Baggs.

Glaze BC2E

Copper blue, cone 06
Molecular formula: $1.0\ Na_2O \cdot 0.132\ Al_2O_3 \cdot 2.73\ SiO_2$
Batch: Powdered sodium silicate ($Na_2O \cdot 3.25\ SiO_2$; equivalent weight, 257) 67; cryolite 24, flint 20, bone ash 9, copper oxide 4, and bentonite 3.

Glaze A

$1.0\ Li_2O \cdot 0.132\ Al_2O_3 \cdot 2.73\ SiO_2$
Batch: lithium carbonate 28.8, clay 13.6, flint 57.6, copper oxide 4.0, and bentonite 3.0.

In the new glazes, all of the soda from cryolite and sodium silicate was replaced by an equivalent amount of lithia in the form of lithium carbonate. An equivalent amount of alumina was supplied by English china clay. The ratio of alumina and silica was the same as in BC2E.

In all early tests, 4% of copper oxide was used to serve by its color as a rough check on the "alkaline color reaction" of the glaze. Later 3.5% of copper oxide was found equally effective with less tendency to produce metallic scums and was used in glaze No. 27 and all succeeding forms.

In all tests, 3% of bentonite was used to aid in suspending heavier ingredients.

Tests were fired at cone 06 and were made on both high flint and ordinary red clay bodies. In most cases, check tests were made after the glaze which remained from the first tests, had been dried on plaster slabs and reground. Such tests were surprisingly uniform and seemed to be a good proof of the insolubility and stable character of the ingredients.

The first tests resulted in a glaze that was a fresh light blue in color and clear and glassy in texture. With the addition of 9% bone ash, it became grainy and semi-mat. Although it was too fluid and seemed to indicate devitrification, it is still uncrazed on a high flint

body to which it was applied more than two years ago.

Several attempts were made to obtain a mat of the aluminous type with this glaze, using the usual oxygen ratio of 3 to 2 for mat glazes. The highest amounts of alumina and silica tried were 0.4 equivalent alumina to 1.65 equivalents silica.

The results were good blue, fairly opaque but shiny glazes which shivered on high flint bodies. These tests indicated that, with an all-lithia RO, high alumina would not be detrimental to copper blue color. They also indicated that such a glaze, to fit, would require a less siliceous body than the one on which it had been used.

Further work on glazes of which the sole RO member was lithia was dropped for the time because of the amount of lithium carbonate which they required. They contained from 29 to 46% of the batch weight of lithium carbonate, which, at that time, retailed at $2.00 per pound in small quantities. The cost of such glazes would be prohibitive for most potters.

The aim of the next group of tests, therefore, was to ascertain what insoluble materials could be used to reduce the amount of lithium carbonate required. Eighteen glaze formulas were calculated, in each of which one or more insoluble fluxes were used in combination with lithia to form the RO which, in turn, was combined with varying amounts of alumina and silica.

From these formulas, many tests were made which gave the following results:

(1) When 0.9 of the RO is lithium oxide and 0.1 lead oxide, the glaze is a good blue, even with as much as 0.4 equivalent alumina and 4.0 equivalents silica at cone 06 on special white bodies.

(2) When zinc oxide, magnesium oxide, or lead oxide, alone or in combination, were substituted for part of the lithia in the RO in sufficient quantities to reduce appreciably the lithium content, the results were greenish and often dirty colors.

(3) When these oxides were employed in combination with feldspar and lithium carbonate, the glazes did not mature at cone 06 and were not promising in color.

(4) When 0.4 equivalent of the RO was supplied by alkalis from feldspar and 0.6 by lithia from lithium carbonate, the glazes were immature at cone 06.

(5) When the RO consisted of 0.4 equivalent soda from cryolite and 0.6 equivalent lithia from lithium carbonate, the result was a deep brilliant blue glaze in which the lithium carbonate content was still too high from the point of view of cost.

(6) When more than 0.4 equivalent of the RO was sodium oxide from cryolite, the glaze was marked by a peculiar crystalline surface.

From these observations, glaze No. 22 was evolved.

Glaze No. 22

$$\left.\begin{matrix}0.5\ LiO_2\\0.4\ Na_2O\\0.1\ KNaO\end{matrix}\right\}\ 0.226\ Al_2O_3\quad 2.85\ SiO_2$$

Batch: lithium carbonate 13.3, Eureka feldspar 19.9, cryolite 19.7, flint 47.1, bone ash 9.0, copper oxide 4.0, and bentonite 3.0.

This combination reduced the lithium carbonate content to 13.3% of the batch and gave a bright blue glaze with a smooth, mat surface. A number of good pieces were made with it, but in studio use the mat surface did not prove to be reliable. It sometimes became shiny while retaining a fresh color and smooth surface, and sometimes became an unpleasant greenish-blue glaze with imbedded crystals of a white "sugary" nature.

To correct the tendencies of glaze No. 22 to form white crystals and to lose the mat surface, various modifications were made. Because these faults had appeared with the introduction of both cryolite and bone ash into the glaze, it was assumed that they might be due in some way to the reactions of these ingredients. Several triaxial blends were made using differing amounts of cryolite, bone ash, and lithium carbonate, with the other ingredients constant. These tests, however, were too complex to be of any help, but the addition of calcium oxide in the form of whiting gave promise of marked improvement. The recalculation of glaze No. 22, with 0.2 equivalent of the RO supplied by calcium oxide, gave glaze No. 27 in which whiting was 7% of the batch and the lithium carbonate was reduced to 10.5%.

Glaze No. 27

$$\left.\begin{matrix}0.41\ Li_2O\\0.32\ Na_2O\\0.07\ KNaO\\0.20\ CaO\end{matrix}\right\}\ 0.226\ Al_2O_3\quad 2.85\ SiO_2$$

Batch: lithium carbonate 10.5, cryolite 15.5, Eureka feldspar 15.6, whiting 7.0, clay 4.1, flint 47.2, bone ash 9.0, copper oxide 3.5, and bentonite 3.0.

Glazes No. 22 and No. 27 were then used for a series of twelve tests. Each test consisted of a group of seven different bodies, with one-half of each body sprayed with glaze No. 22 and one-half with glaze No. 27. The groups were fired at different temperatures ranging from cones 08 to 01 in both gas and electric kilns.

As would be expected, all faults were most marked on red clay and were more pronounced when the glaze was applied on the unfired clay than when applied on the biscuit. Both glazes were uncrazed and were uniformly best in color and texture on high flint bodies.

On the red bodies, both glazes tended to become greener at temperatures higher than cone 04, but on white bodies they lost little of the bright blue color at cone 01, the highest temperature to which any of the tests have been fired.

Glaze No. 27 showed no white crystals, but on a few tests it boiled slightly. On the other hand, glaze No. 22 showed no boiling, but on many tests it formed large crystals and unpleasant surfaces. From this series, it was concluded that the addition of whiting eliminated large white crystals but induced a tendency to boil under some conditions. On the whole, glaze No. 27 proved a more predictable glaze than No. 22 and supplanted the latter in tests and in use on actual pottery pieces.

Glaze No. 27 has been used by many members of the pottery classes under normal laboratory conditions since November, 1936, and its behavior has been observed on several types of bodies and under a wide variety of circumstances. It has continued thus far to fit high flint bodies and can be developed, without crawling, on such bodies in one firing. On regular red clay, it crazes immediately upon cooling but does not chip off. It

is a popular glaze on such clay because of the decorative effects obtainable with the copper blue over scraffito, mishima, or slip painting in white, and for that reason it is desirable on pieces when crazing is not objectionable. It is especially liked for ceramic sculpture because of its pleasing tactile qualities and its subdued gloss, because it does not craze on high flint casting bodies, and because it does not run in firing.

When the copper is omitted and no other coloring oxide is used, it is a pure white, waxy, semiopaque, semimat glaze. Without the 9% bone ash, it is a clear glaze, useful for developing alkaline colors in underglaze. The white glaze forms an excellent background for decoration with soluble salts which it develops into fresh clear colors. Coloring oxides are used to produce the characteristic alkaline colors. Small amounts of chromium give lemon yellows; uranium, canary yellows; chromium and copper, apple and camellia greens; nickel, green-browns; and manganese, pink-purple colors.

On the other hand, it has shown a number of faults. The mat texture is not consistent, for the glaze frequently becomes quite shiny when fired over cone 06. This probably is due to the bone ash which appears to go completely into fusion at this temperature and thus ceases to be an opacifier. Several times it has shown a mysterious efflorescence both on the red clay and on the high flint bodies. Occasionally it becomes unpleasantly granular in parts of the piece as if struck by fumes or vapors. Quite frequently it boils on the inside of deep pieces and within footrims, especially if the glaze has been too thickly applied or if the firing has been too rapid.

Glaze No. 26 has been extensively used and has proved an interesting and satisfactory glaze when used on high flint bodies. Because it is an intermediate step between Nos. 22 and 27, it may display the unfavorable qualities of either glaze, but its worst feature is that it occasionally develops grainy surfaces.

Glaze No. 26

$$\left.\begin{matrix}0.46\ Li_2O\\0.36\ Na_2O\\0.09\ KNaO\\0.09\ CaO\end{matrix}\right\}\ 0.226\ Al_2O_3\ \ 2.85\ SiO_2$$

Batch: lithium carbonate 12.0, cryolite 17.8, Eureka feldspar 17.9, whiting 3.2, clay 1.9, flint 47.2, bone ash 9.0, copper oxide 3.5, and bentonite 3.0.

From the viewpoint of convenience in small laboratories, the virtues of these glazes are their ease of preparation and their "keeping" qualities after grinding. They may be hand-ground or mill-ground in a short time, for they require only simple mixing of finely ground materials. They do not become hard or gummy upon standing after preparation, and they have been used after aging several months with no apparent effect upon their ease of application or appearance after firing.

These glazes, with from 9 to 12% lithium carbonate, cost more than other glazes, but they are not too expensive for general use by studio potters. When these studies were begun, the cost of the lithium carbonate used was from 18 to 24 cents per pound of dry glaze. The present price of lithium carbonate is $1.45 per pound in 20-pound lots, which reduces the cost to 13 to 15 cents per pound of glaze. It seems probable that lithium carbonate will become much cheaper as the demand for lithium compounds in new forms of industry, particularly air conditioning and thermal glass production, becomes greater.

In an attempt to develop a glaze as nearly "foolproof" as possible, many variations of glaze No. 27 have been tried, and twenty-five subsequent formulas were calculated and tested as follows:

(1) To correct efflorescence, 0.05 equivalent barium oxide from barium carbonate was tried. It had an unfavorable effect on the texture, forming peculiar, shiny crystals, but the efflorescence was unchanged. It did, however, seem favorable to the color and the opacity.

(2) The silica was kept constant at 2.85 equivalents, and the alumina was increased to as much as 0.3 equivalent. The mat texture was improved as a result, but the color became somewhat green.

(3) The alumina was kept constant at 0.226 equivalent, and the silica was increased to 4.5 equivalents. The color and texture were not noticeably changed.

(4) All of the alumina which was not furnished by cryolite was supplied by feldspar, thus reducing the lithium carbonate to 9.7%, without noticeable effect.

(5) Ten different feldspars were substituted for the Eureka feldspar, by weight instead of molecular equivalents, without essentially modifying the glaze.

III. Conclusions

These investigations have demonstrated the following points:

(1) It is both possible and feasible to make satisfactory raw alkaline glazes in which all ingredients are insoluble or but slightly soluble.

(2) Characteristic alkaline colors can be obtained in glazes in which the RO group is composed entirely of lithia from lithium carbonate.

(3) These colors can also be obtained in glazes which contain from 10 to 12% lithium carbonate, supplemented by cryolite and feldspar.

(4) These lower lithium content glazes can contain unusually high proportions of clay, whiting, feldspar, and other ingredients commonly considered detrimental to alkaline colors.

(5) The faults which occur in these glazes occur also in glazes which contain no lithium carbonate and are probably due to constituents other than lithium carbonate.

(6) The cost of these glazes, while high, is not prohibitive at the present time.

(7) These glazes possess qualities of color and texture which make them of value to ceramic artists.

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CRITICAL STUDY OF THE DIFFERENTIAL THERMAL METHOD FOR THE IDENTIFICATION OF THE CLAY MINERALS*

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Abstract

An apparatus is described for studying clay minerals by the differential thermal method, which has some advantages over previous types of apparatus. Thermal curves are given for many of the pure clay minerals for use as standards of identification. The use of this method quantitatively for the determination of the relative amounts of clay minerals in a natural clay is discussed, and examples are given for a number of high alumina clays.

Introduction

Any one who has worked with clays or soils realizes the difficulty in identifying the clay minerals in the finer fractions. The petrographic method, which is so satisfactory for crystals more than a few microns in size, is useful in the smaller sizes only to a limited extent. The X-ray, on the other hand, is able to identify the finer grained clay minerals if they occur in fairly large proportions, but when small amounts are combined with large amounts of some other mineral, it is difficult to recognize the smaller portion because they are all sheet minerals with many common lines.

This difficulty becomes more pronounced as the crystal size decreases because of the broadness and general indistinctness of the X-ray lines. In looking about for some additional way of identifying the clay minerals, the differential thermal method seemed promising in view of the qualitative work which had already been done with it. This paper, therefore, discusses the thermal method for the identification of the clay minerals, using an improved apparatus which attempts to minimize some of the errors occurring in previous investigations so that quantitative results can be achieved. The various factors influencing the magnitude and position of the absorption peak in a given mineral are also studied.

In Part I, the qualitative identification of minerals will be taken up, including a comparison of the present data with those of other experimenters. In Part II, the differential thermal method will be discussed from the viewpoint of quantitative determinations.

Part I. Qualitative Determination

I. Previous Work

The thermal method of identifying minerals has been investigated by a number of authors. The differential thermal method was suggested in 1887 by Le Chatelier.[1] Later Wallach[2] showed how this method could be used to identify types of clays. Satoh[3] gave a number of thermal curves of Japanese fire clays. In 1933, the fine work of Orcel and Caillère[4] on the bentonite minerals brought out the value of this method more clearly than any one before. Granger[5] discussed the thermal analysis of clay a little later, and Orcel[6] then presented a complete paper, giving thermal curves of most of the known clay minerals as well as curves of many natural clays. Orcel brought out still further the value of this method for identification purposes. In a study of the kaolin minerals, Insley[7] obtained thermal curves of kaolinite and dickite. A thermal curve of talc was obtained by Ewell, Bunting, and Geller,[8] which showed the high temperature stability of this mineral. One of the latest papers on the subject by Jourdain[9] gives thermal curves for a number of the clay minerals. Thilo[10] also shows curves for pyrophyllite.

A study of this literature will indicate continued improvement in the methods to obtain the thermal curves and a greater purity of samples of the clay minerals. Owing to differences in apparatus and methods, however, it is not possible to compare the results of different experimenters more than in a general way, but certain discrepancies are noted which the writer hopes to clear up in this paper. As far as is known, no quantitative measurements by the thermal method have been

* Received September 22, 1938.

[1] Le Chatelier, "De L'Action de la Chaleur sur les Argiles," *Bull. Soc. Min.*, **10**, 204 (1887).

[2] H. Wallach, "Analyse Thermique des Argiles," *Compt. Rend.*, **157**, 48 (1913).

[3] Shinjo Satoh, "Heat Effects on Fire Clays and Their Mixtures," *Science Repts., Tôhoku Imp. Univ. (Series 3)*, **1**, 3 (1923).

[4] J. Orcel and S. Caillère, "L'Analyse Thermique Différentielle des Argiles à Montmorillonite (Bentonites)" (Differential Thermal Analysis of Montmorillonite Clays (Bentonites)), *Compt. Rend.*, **197** [15] 774–77 (1933); *Ceram. Abs.*, **13** [6] 160 (1934).

[5] A. Granger, "Thermal Analysis of Clay," *Céramique*, **37** [552] 58 (1934); *Ceram. Abs.*, **14** [1] 23 (1935).

[6] J. Orcel, "L'Emploi de L'Analyse Thermique Différentielle dans la Detérmination des Constituants des Argiles, des Latérites, et des Bauxites" (Differential Thermal Analysis for Determination of Constituents of Clays, Laterites, and Bauxites), *Congr. Internat. Mines, Met. Geol. Appl., 7e Session, Paris, 1935, Geol.*, **1**, 359–73 (1936); *Ceram. Abs.*, **16** [7] 218 (1937).

[7] H. Insley and R. H. Ewell, "Thermal Behavior of the Kaolin Minerals," *Jour. Research Nat. Bur. Stand.*, **14** [5] 615–27 (1935); R.P. 792; *Ceram. Abs.*, **14** [8] 201 (1935).

[8] R. H. Ewell, E. N. Bunting, and R. F. Geller, "Thermal Decomposition of Talc," *Jour. Research Nat. Bur. Stand.*, **15** [5] 551–56 (1935); R.P. 848; *Ceram. Abs.*, **15** [2] 76 (1936).

[9] A. Jourdain, "Studies of the Constituents of Refractory Clays by Means of Thermal Analysis," *Céramique*, **40** [593] 135–41 (1937); *Ceram. Abs.*, **16** [11] 357 (1937).

[10] Erich Thilo and Heinz Schünemann, "Chemical Studies of Silicates: IV, Behavior of Pyrophyllite, $Al_2(Si_4O_{10})(OH)_2$, on Heating and the Existence of a 'Water-Free,' Pyrophyllite, $Al_2(Si_4O_{10})O$," *Z. anorg. allgem. Chem.*, **230** [4] 321–35 (1937); *Ceram. Abs.*, **16** [10] 311 (1937).

attempted, although such a possibility was suggested by Orcel.[6] A more detailed comparison will be made later of the previous work in relation to the curves obtained in this paper.

II. Design of the Apparatus

A cross-section of the thermal furnace is shown in Fig. 1. The specimens are held in two sockets drilled into a heavy nickel block, which tends to minimize the thermal gradients. The neutral body and the test specimen are placed laterally in the furnace rather than longitudinally, because this assures the same heat input to each throughout the whole run and also gives the uniformity of the curves at the start.

recorded on this same bromide paper by a signal lamp, which is flashed every time the potentiometer reading comes to an even 50° interval.

The rate of temperature rise of the furnace is controlled by a liquid rheostat in which dilute sulfuric acid flows through a capillary tube to a battery jar into which are suspended two carefully shaped graphite electrodes, so that the current is increased at such a rate that a close approximation to the desired temperature rise of 12°C per minute is obtained. The main difficulty with this simple equipment is that changes in room temperature affect both the resistance of the acid and also the heat loss from the furnace, so that certain corrections have to be made in the acid flow rate from

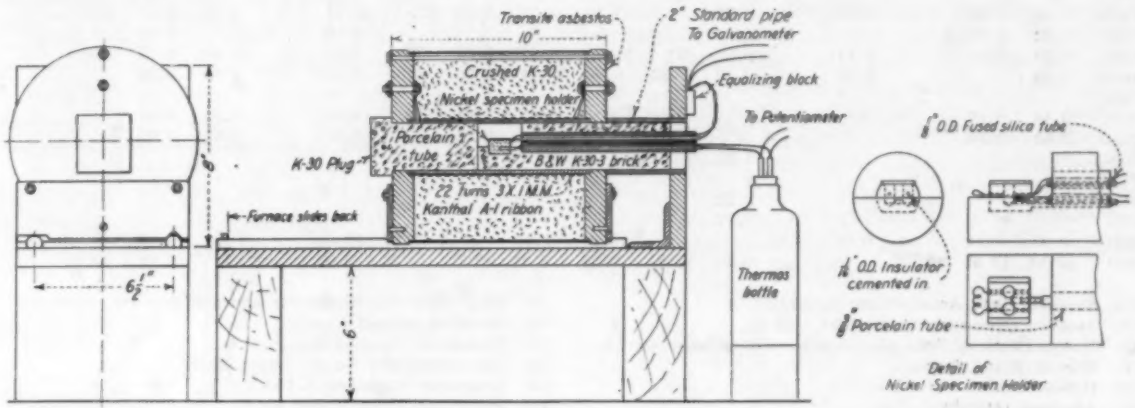

FIG. 1.—Thermal analysis furnace.

There are no other special features of the furnace except the Kanthal winding, which allows running the furnace continuously above 1000°* without danger of burn-outs; the sliding furnace also allows the specimen block to be exposed for changing specimens without disturbing the thermocouple connections.

Contrary to most of the previous work, the temperature of the specimen is measured by a separate thermocouple, imbedded in the center of the nickel block, which is connected directly to the potentiometer with the cold junction in ice. This eliminates certain complications of the temperature measurement and gives a temperature which can not depart more than a few degrees from the temperature of the sample. In fact, a temperature taken in the block itself is more suitable for a base than the temperature of the neutral body, which may show variations owing to shifts in the couple position.

The differential temperature is read with a recording galvanometer of such a resistance that no shunt is required. A continuous record is produced on a strip of bromide paper, a method superior to the point-by-point method, which may lose small but important characteristics of the curve. The actual temperatures are

* Centigrade temperature will be used throughout this paper.

time to time which introduces some unevenness in the temperature rise. Small variations in rate, however, do not seem to affect the area appreciably under the various peaks.

III. Samples Used

Table I shows the generally accepted relation between the clay minerals, although there is no uniformity of opinion on just which one should or should not be included. In Table II there are shown the chemical

TABLE I
CLAY MINERALS

Kaolin	Montmorillonite	Micaceous	Hydrated alumina
Kaolinite-anauxite	Montmorillonite-nontronite	*Muscovite-sericite	Gibbsite
Dickite	Beidellite	Potash clay	Diaspore
Nacrite	Talc*		
Halloysite	Magnesium clay		
Allophane	Pyrophyllite*		

* While these minerals are not usually considered to be clays because of their large crystal size in nature, they do acquire claylike properties when finely ground.

analyses and the origin of the various clay minerals tested. In view of the limitations of space, only the purest mineral obtainable of each type is listed,

although in most cases several samples have been tested; any great deviation will be mentioned in connection with the curves. The samples were air-dried, ground in a mortar until they passed a 150-mesh screen, and then were tamped lightly into the test chamber; the junction of the thermocouple was exactly centered. This tamping was done carefully so that as far as possible various minerals were tamped approximately to the same density. Between 0.3 and 0.4 gram of material is necessary for this purpose, the small amount before about one second; this produces a horizontal black line across the film corresponding with this temperature. The time is noted, and the potentiometer is set ahead to the millivolt reading corresponding to 100° and so on until the last reading of 1000° is reached, after which the differential galvanometer circuit is opened so that a zero reading can be obtained on the film. The flow of acid through the capillary tube is controlled if necessary to maintain a time interval of about 4 minutes for each 50° interval.

TABLE II

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SiO_2	44.70	48.80	46.35	44.75		27.61	61.34	65.35	53.68	47.28	41.38	50.20		55.64	50.10	1.6	9.7
Al_2O_3	38.64	35.18	39.59	39.49		32.29	0.71	29.25	0.60	20.27	9.84	16.19		16.18	25.12	65.0	90.2
FeO											Tr.				1.52		
Fe_2O_3	0.96	1.24	0.11	0.53		0.23		0.10	1.12	8.68	27.47	4.13		2.68	5.12	None	
TiO_2	0.22	0.61										0.20			0.50	1.1	
CaO	0.24	0.22		0.13		0.02	Tr.	None	0.52	2.75	Tr.	2.18		1.80	0.35	None	
MgO	0.08			0.19		0.10	32.32	0.05	25.34	0.70	Tr.	4.12		8.88	3.93		
BaO																	
K_2O	0.14	0.40				0.10		0.05	0.07	Tr.	Tr.	0.16		5.16	6.93		
Na_2O	0.62	0.25							3.00	0.97		0.17		0.04	0.05		
P_2O_5						1.31											
F			0.15														
SO_3						0.12											
CO_2						0.72											
H_2O-	0.64	1.16		0.61				0.08	7.28		12.10	15.58		9.72	1.90		
H_2O+	13.88	12.81	13.93	14.40		18.05	5.81	0.25	8.24	19.72	9.25	7.57			7.18	33.0	

(1) Kaolinite (Ione, Amador County, Calif.).
(2) Anauxite (Newman pit, near Ione, Calif.).
(3) Dickite (National Belle mine, Red Mountain, Ouray, Colo.).
(4) Nacrite (Brand, Saxony).
(5) Halloysite (Anamosa, Iowa).
(6) Allophane (Morehead, Ky.).
(7) Talc (Manchuria, very pure sample).
(8) Pyrophyllite (More County, N. C.).
(9) Magnesium clay (Hector County, Calif.).
(10) Beidellite (Beidell, Colo.).
(11) Nontronite (Sandy Ridge, N. C.).
(12) Montmorillonite (Smith County, Miss.).
(13) Muscovite (Keystone, S. Dak.).
(14) Potash clay (High Bridge, Ky.).
(15) Illite, colloidal fraction (Maquoketa shale, near Gilead, Ill.).
(16) Gibbsite (Dutch Guiana).
(17) Diaspore (Rolla, Mo.).

Analyses (3) and (7), see footnotes 7 and 8.
Analyses (1), (2), (4), (6), (8), (9), (10), (11), (12), (14), Dr. Ross, U. S. Geol. Survey.
Analyses (16) and (17), Babcock and Wilcox Co.
Analysis (15), *Amer. Mineralogist*, 22, 818–23 (1937).

ing desirable in cases where the clay can be obtained only in small quantities. In some cases, the clay mineral is dried at 110°C to constant weight before the test, and (as will be shown later) this drying materially affects the initial part of the curve for many of the minerals.

IV. Method of Conducting the Test

After the sample has been placed in its socket in the nickel block, a nickel cover is put on top of the block to protect both the neutral body, which is calcined alumina, and the specimen from the direct radiation of the furnace walls. The furnace is then slid over the specimen. The liquid rheostat is adjusted so that the ends of the electrodes are just touching the acid, and a shunt resistance regulates the initial current to five amperes. As soon as the switch is closed to pass this current through the furnace, the acid is started flowing through the capillary tube and the recording galvanometer is started. The potentiometer is then set at a millivolt reading corresponding to 50°, and the needle of the potentiometer galvanometer is watched until it reaches the zero mark, at which time the signal switch is closed

The method described could be considerably simplified if a program controller maintained the temperature definitely on schedule and an automatic contactor flashed the 50° signals. It is hoped to construct such a device in the future.

V. The Kaolin Minerals

The thermal curves for the kaolin minerals are shown in Fig 2. In all of these thermal curves, the first vertical line represents 50°, with 50° intervals up to 1000°. All of these minerals are characterized by a strong exothermic peak in the region of 980°, and, as far as the writer has been able to determine, no minerals outside this group have this characteristic. The minerals in this class were of high purity and certainty of composition so that the results are much more definite than in the other classes. The thermal curves for nacrite, dickite, and kaolinite show only a small deviation from a straight line in the initial portion owing to absorbed moisture, but the beginning of an endothermic effect is found in all of them at about 475°. The nacrite shows a comparatively long peak running from 610° to 670°. The dickite, on the other hand, shows a rather long

range of slight heat absorption and then a rather sudden peak at 700°. The kaolinite has a definite peak at 610°. It is possible, therefore, to distinguish definitely these three kaolin minerals by the thermal curves, because a mixture of kaolinite and dickite would give a double peak rather than the broad peak of the nacrite.

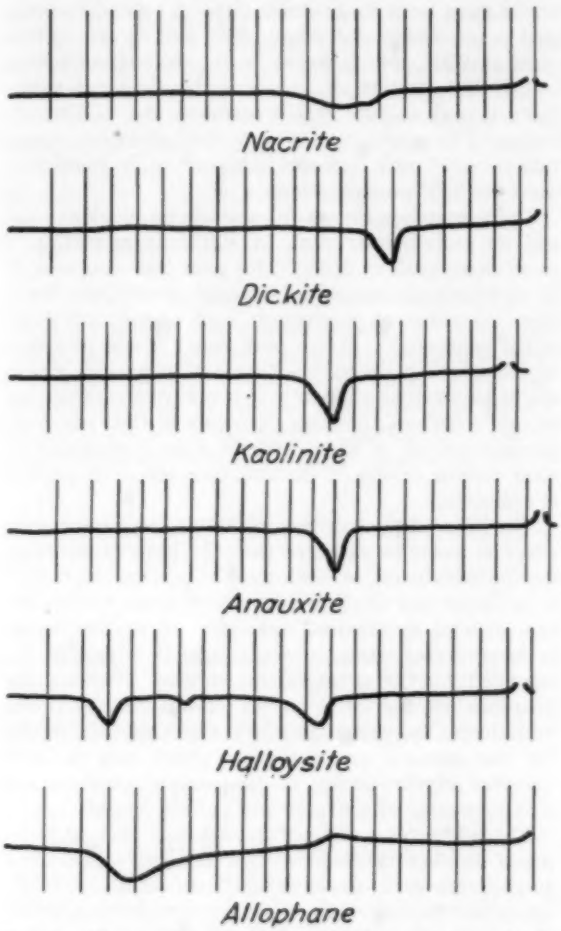

FIG. 2.—The exothermic peak at 980° is not completely shown on these curves.

Allowing for differences in heating rate and size of sample, the kaolinite curves of Orcel and Jourdain agree with that shown here except for the large, low temperature absorption peak, due probably to the fine grain size of their samples.

The anauxite gives a curve substantially the same as the kaolinite except for a slightly smaller area under the endothermic peak, which might be expected from the lower content of combined water. It must be concluded, therefore, that the thermal method can not distinguish between anauxite and kaolinite, and a chemical analysis must be made to assign values to the kaolinite-anauxite series.

The halloysite is readily distinguished from the kaolin minerals named because of the two low temperature peaks, which are sharp and distinct, the first at 150° and the smaller at 325°. These peaks do not show to any extent if the material has been previously heated to 110°. It is advisable, when identifying clay minerals, to run them in the air-dried condition and, if possible, with the same moisture they contained in the ground. Undoubtedly in the past, some so-called halloysite has really been fine-grained kaolinite, and in a mixture of the two there is sometimes great difficulty in distinguishing between them. It will also be noticed that the main absorption peak at 580°C in halloysite comes at a lower temperature than for the kaolinite, as might be expected from the finer grain size. A fine-grained kaolin will show the first absorption peak but not the second. The halloysite curves of Orcel and Jourdain indicate only one broad low temperature peak rather than two separate ones.

The mineral, allophane, is of such fine grain size as to be practically amorphous, and therefore the large endothermic effect at low temperatures, which shows a peak at 180° but extends over a long range, is more or less to be expected. The low exothermic peak at 600° is difficult to explain at present because the usual exothermic peak due to the amorphous-alumina–gamma-alumina change occurs in its usual position. Because this material is noncrystalline, it is perhaps not justified to group it with the kaolin minerals, but at present this seems to be the most logical location.

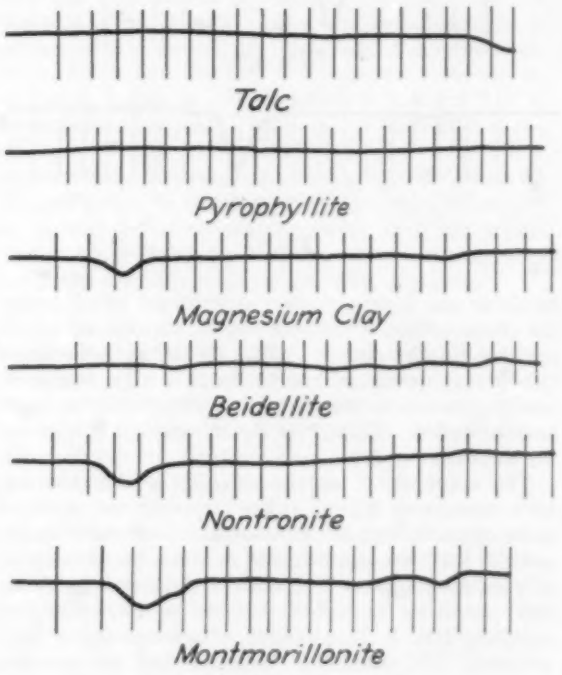

FIG. 3

In conclusion, the kaolin minerals as a class can be determined definitely by the exothermic peak at 980°C, and the various members of the group can be distinguished by the endothermic effects which, except for anauxite, are unique for each one of the minerals.

VI. The Montmorillonite Minerals

These minerals are believed to have a symmetrical sheet structure similar to pyrophyllite, but owing to the minute and imperfect crystallization, there is still some doubt as to the exact crystal structure. Contrary to the case of the kaolin minerals, many minerals of this group are difficult to obtain in the pure form, and because of the fine grain size the X-ray does not always indicate when small admixtures occur. Only by studying a great number of these minerals from different localities can it be definitely determined which peaks are characteristic of the pure mineral studied and which are due to admixtures. While the minerals listed in this group are considered to be of a high degree of purity, there is no certainty that all admixtures have been excluded. Curves for the minerals of this group are shown in Fig. 3.

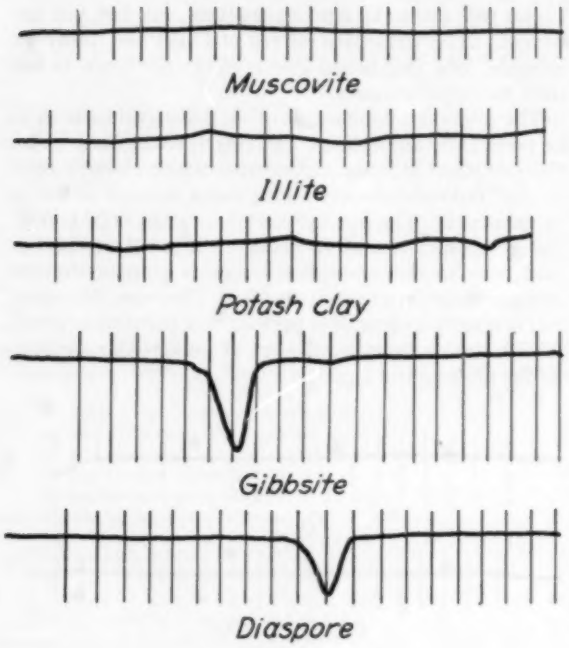

FIG. 4.

The specimen of montmorillonite is characterized by a strong double peak at low temperatures, which is quite characteristic of this mineral. The endothermic peak at 870° has also occurred in a number of samples of montmorillonite The other endothermic peak at 690° seems to be rather variable between different samples, but it is probably characteristic of this mineral. The curves of Jourdain and Orcel agree perfectly with this curve, except that the 690° peak is larger, corresponding exactly with the curve for Wyoming bentonite (Fig. 5).

Nontronite is a mineral believed to be more or less isomorphous with montmorillonite, and it is therefore not surprising to find that the thermal curve is somewhat similar with a low endothermic peak at 870°. It can be distinguished, however, at least in this specimen, from the montmorillonite by the initial peak which is much less broad than the double peak of the montmorillonite. The curve agrees perfectly with that of Orcel for this mineral.

The curve for the beidellite shows a single low temperature peak. Because the sample had been dried at 110°C, this peak is not as prominent as it would have been in air-dried clay. The endothermic peak is also found at 575° and 870° and an exothermic peak at 900°, which seems to be the distinguishing feature of this mineral. There is also the small endothermic peak at 690° which occurs in the montmorillonite. This curve agrees with that of Orcel except that the 690° peak is absent in his curve; in Jourdain's curve the 870° peak is absent.

The magnesium clay shows a single low peak at 175° and an endothermic peak at 800°; there is also a small sharp peak at 275°. This peak has been noticed on at least eight records of minerals containing fairly large quantities of magnesium, such as talc and some of the bentonites. It is a peak which would probably be missed if a point-by-point method were used, and it might be thought accidental if it occurred on only one record. Because, however, it occurs at the same temperature on all of these runs, it must correspond to some definite change in the structure, which at present is unknown.

The mineral, pyrophyllite, shows no low temperature effect as would be expected from the large crystal size. On the other hand, the endothermic peak at about 625° is so broad and shallow that it is difficult to identify this mineral by thermal methods. It usually occurs in large crystal sizes, however, and it is readily determined by the petrographic method. Neither the Jourdain nor the Orcel curves for this mineral agrees with that of the writer, and Orcel states that the results for this mineral are variable. There can be little question of the purity of the sample used by the writer, because of the large and perfect crystals.

The talc gives a distinct endothermic peak at 990°, which is characteristic of this mineral. The small endothermic peak, shown at 600°, can not be due to the impurities because this particular sample of talc was of great purity, but some other pure samples of talc have shown only the point at 990°. The small peak at 275° is also present on this curve. The relatively high temperature of the main endothermic peak indicates the great strength of the OH bonds in this crystal. This curve agrees with those of Orcel and Ewell.

VII. Micaceous Clay Minerals

These minerals, like the preceding, can not be obtained in as pure form as the kaolin minerals, and there is still a great deal of work to be done in this class. In Fig. 4, a curve of muscovite is given; although muscovite is not usually considered as a clay mineral, it is included because of its close association. The curve shows a broad absorption peak at about 600°, which is so shallow as to make identification of this mineral by the thermal method not too certain. Several specimens of muscovite from different sources have shown identi-

cal curves. On the other hand, Insley* stated in a private communication that a muscovite from Laurel, Md., showed a broad but distinct endothermic peak at 840°.

The potash clay shows a rather complex curve with a double absorption peak at a low temperature, due to surface water and endothermic peaks at 690° and 900°, which are fairly sharp and distinct. The exothermic peak at 490° is still to be explained, because it would hardly seem to be due to organic matter in this material.

The illite gives a curve somewhat analogous to the potash clay but with fewer low temperature effects, which would indicate a less active surface or a larger grain size. The endothermic peaks at 600° and 880°, although small, are sufficiently distinct for identification purposes. The 600° peak corresponds closely with that of muscovite.

VIII. Hydrous Alumina Minerals

Figure 4 also shows the curve for gibbsite, indicating a large heat absorption at the comparatively low temperature of 350°. This large effect would be expected because the mineral contains 33% water, which is twice that of the kaolin minerals. It is interesting to observe the double peak in the mineral, which

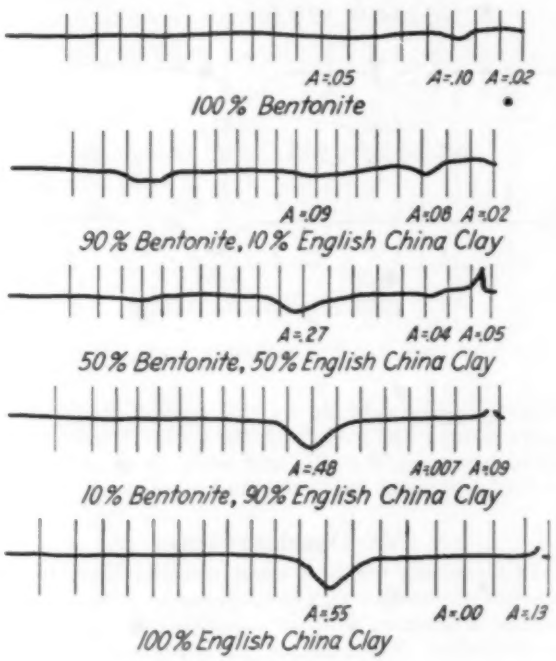

FIG. 5.

may be due to some admixture, because some other gibbsites contained in high alumina clays show only a single peak at this point. It was impossible to obtain a pure crystalline gibbsite, which would make the theory of an admixture possible. The small endothermic peak at 550° and the small exothermic peak at 980° indicate the presence of a few per cent of kaolinite.

* Herbert Insley, National Bureau of Standards.

The diaspore is a crystalline material, but it has some silica admixture. It seems difficult, in fact, to obtain a sample of diaspore which does not have about 10% of silica. Is this silica free quartz, or does it occur in the diaspore structure? It is assumed here that it is thermally inert material. Diaspore gives a single definite peak at about 550°, but it shows no exothermic peak at 980° and it need not be confused with the kaolin minerals.

Both of these minerals give results in good agreement with Jourdain and Orcel.

Part II. Quantitative Determination

I. Measurement of Heat Effect

If it is desired to determine precisely the amount of a hydrous mineral in a clay by the thermal method, it is necessasry to use some definite measure of the heat effect. The measure need not be absolute, because it is difficult to make such a measurement, but it should be relatively accurate as compared with the standard samples. As a basis for this measurement, the height of the peak on the thermal curve may be used, which is the maximum temperature difference between the test sample and the neutral body. It has been found, however, that the height of the peak varies considerably with small changes in heating rate; therefore, in this work the area under the peak has been found to be satisfactory for measuring the heat effect because this quantity is not greatly affected by small changes in heating rate. In defining the area under the peak, certain limits must be set; otherwise the area will be somewhat indefinite. In general, a straight line is drawn from a tangent to the curve on both sides of the peak, and the area under this line is determined. There are some cases, however, where one peak is disturbed by adjacent peaks, in which case it is necessary to resolve the curve into its elementary peaks, each one representing a particular heat affect. In most cases, this can be done readily with considerable precision.

II. Reproducibility

In measuring the heat effect, certain variables enter into the measurement which must be taken into account for quantitative work. One of the most important variables is the physical property of the sample when packed in the test cavity. With care, it is possible to pack the sample in with sufficient reproducibility to check the heat effect within 2%, but there are cases where the properties of the mineral itself change, such as density, specific heat, and thermal conductivity as various types of clay are used. An example is shown by kaolin which, when packed in the test cavity in the usual manner, has a density of 0.70 g. per cu. cm., whereas a hard Missouri flint clay packed in the same manner has a density of 1.19. Both of these materials are essentially pure kaolinite, and yet one will naturally give a much greater heat effect than the other. At present, a method of eliminating this variable has not been determined, but it happens to a serious extent only in the case mentioned. The change in heat effect with the variation in physical properties of a single mineral are shown in Table III.

The heating rate, as explained before, influences both the temperature at which the peak comes and also the height of the peak, but as far as has been determined, it affects only slightly the area. It may be concluded, therefore, that any reasonable control of temperature rise will give little difficulty in quantitative work.

There is also a number of other factors which may affect the reproducibility of the result, but all of these effects can be minimized by careful technique. Among these are the position of the thermocouple, which must

TABLE III

Materials	Area under curve (sq. in.)
Pure kaolinite crystals	0.45
No. 1 English china clay	0.55
Hard Mo. flint clay	0.64

be accurately centered in the sample, and the calibration of the couple, which must be checked. For example, in some of the first runs, there was difficulty in obtaining reproducible results because the moisture from the sample passed out through the thermocouple tube and condensed in the cooler portions in such a way that several errors in the temperature resulted. It should also be remembered that the resistance of the couple current changes with the temperature and

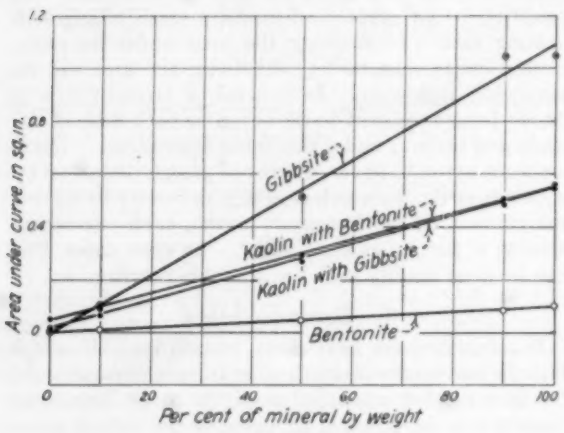

FIG. 6.

that the relation between e.m.f. and temperature is not linear. These effects compensate each other to some extent, giving an average sensitivity of 1.5° per mm. deflection on the record.

III. Individuality of Separate Heat Effects in Mixtures of Minerals

To ascertain the proportionality between the amount of minerals in the mixture and their respective heat effects, a series of mixtures was made of kaolin and montmorillonite, giving the curves in Fig. 5. If the area under each endothermic peak is plotted against the percentage weight of the mineral, a curve will result, such as is shown in Fig. 6, indicating proportionality between the weight of mineral and the heat effect, *i.e.*, each mineral acts independently of the other. The maximum deviation of the points from a straight line is 5% and the average 2%. It is interesting to note that, in many cases, amounts as small as 1% of a

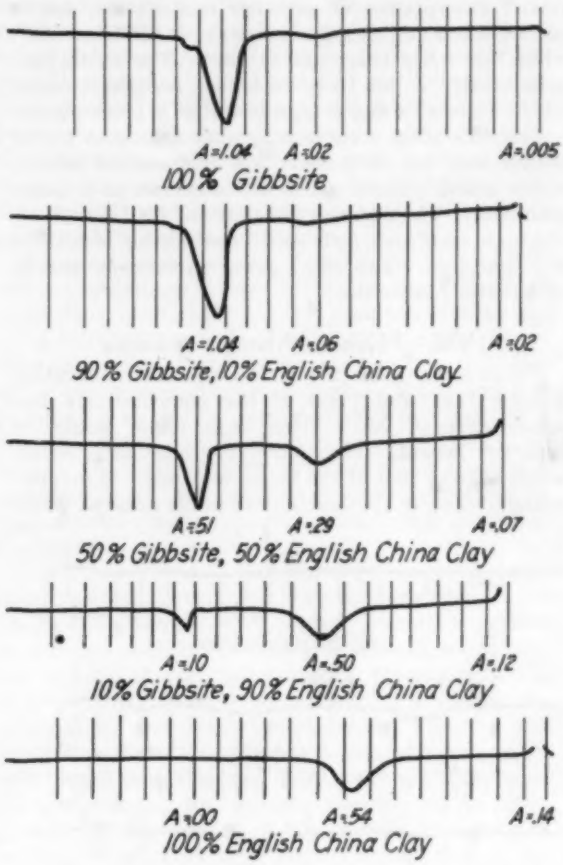

FIG. 7.

mineral can be detected by this method. A similar series of runs was made with the kaolin-gibbsite mixtures (shown in Fig. 7), and when these areas are plotted, a straight line is obtained as shown in Fig. 6.

IV. Disturbing Factors

In measuring the heat effect quantitatively, there are factors entering in which appear to influence the results in addition to those variables listed under reproducibility. For example, the particle size has a distinct influence on the heating curve, the finer fractions giving up their heat more rapidly than the coarser fractions, which is expected from the physical nature of the crystal. To show this more clearly, a sample of Edgar plastic kaolin from Florida was fractionated in the centrifuge to give a series of monodispersed fractions as shown in Table IV. The heating curves for this set of fractions are shown in Fig. 8. The initial part of the endothermic curve occurs at the same temperature, and the peak comes at about the same temperature in all cases, but the finer the particle the more rapidly

TABLE IV

INFLUENCE OF PARTICLE SIZE

Edgar plastic kaolin	Completion of endothermic reaction (°C)	Endothermic maximum (°C)
10–44μ	670	600
0.5–1.0	650	605
0.25–0.5	630	605
0.1–0.25	615	600
Less than 0.1	610	600

the curve comes back to the zero line. Incidentally, this method might be used for a measure of particle size.

Particular attention is called to the finest fraction which gives a curve distinctly different from the others. The fine fraction curve gives a normal endothermic

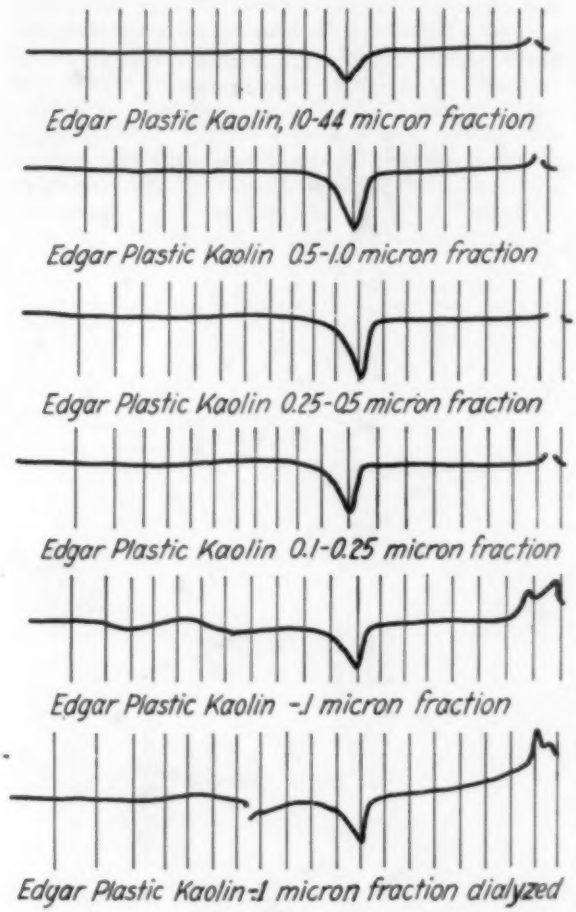
Edgar Plastic Kaolin, 10-44 micron fraction
Edgar Plastic Kaolin 0.5-1.0 micron fraction
Edgar Plastic Kaolin 0.25-0.5 micron fraction
Edgar Plastic Kaolin 0.1-0.25 micron fraction
Edgar Plastic Kaolin -.1 micron fraction
Edgar Plastic Kaolin-.1 micron fraction dialyzed

FIG. 8.

peak, but other characteristics, such as the sudden drop in temperature at 375° and the large double exothermic peak at 900° to 1000°, are peculiar and difficult to explain. Thinking that some of this peculiarity may have been due to adsorbed ions in the fine fraction, the sample was dialyzed and run again, producing a curve of somewhat different but quite similar nature. This curve can be explained either by the fact that there is a mineral in the fine fraction for which there is no prototype in the pure specimen or

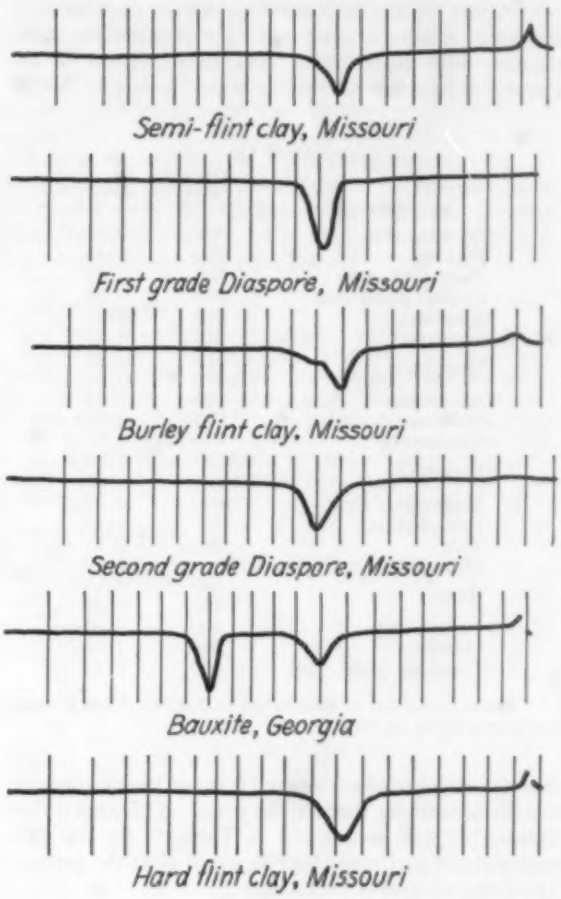

FIG. 9.

that the greatly increased surface area gives effects quite different from the same mineral in a coarser state of aggregation.

It is found, of course, that different clay specimens shrink to different amounts on heating in the test. Some of the montmorillonite samples shrink to a great degree so that a large space exists around the sample preventing any contact with the walls of the cavity. On the other hand, the purer kaolins and high aluminous materials show little shrinkage up to 1000°C, and a few, such as dickite, show an actual expansion. It would be expected that this shrinkage, which changes the density, specific heat, and thermal conductivity of the specimen as well as its ability to give up heat to the walls of the cavity, would influence the heating curve.

There are also conditions where the peaks of two minerals will somewhat overlap, which makes the determination of the area a little difficult. This, however, can be taken care of in most cases by analyzing the curve into its individual components by graphical

methods. There are cases, however, where the overlapping is so close that a careful analysis of the curve is impossible.

V. Selection of Peaks for Each Mineral

In Table V, the important peaks for each mineral are listed, which are most useful for quantitative work, together with their areas. The measurement of the amount of any one mineral in a clay is carried out by

TABLE V

Mineral	Selected peaks (°C)	Area* (sq. in.)
Nacrite	625	0.35
Dickite	700	0.42
Hard flint clay	610	0.64
English china clay	610	0.55
Kaolinite	610	0.45
Anauxite	610	0.37
Halloysite	575	0.33
	310	0.03
Allophane	190	1.22
Montmorillonite	875	0.08
Nontronite	860 (ex.)	0.07
Beidellite	700	0.03
	575	0.03
Magnesium clay	800	0.07
Pyrophyllite		0.16
Talc	990	0.17
Muscovite		0.10
Illite	600	0.15
	890	0.01
Potash clay	900	0.08
Gibbsite	360	1.05
Diaspore (corrected)	550	0.61

* These areas can be converted to degrees times seconds by multiplying by 18,300.

first determining which mineral it is and then by measuring the area under the selected peak. This area is then divided by the area given in Table V for the pure material and multiplied by 100, which gives the percentage of the mineral in the mixture.

VI. Examples of Quantitative Analysis of Clays

To bring out this method of computation more clearly, a number of high alumina clays has been analyzed, both thermally and chemically. These clays are particularly suited to thermal analysis because the minerals contained are kaolinite, gibbsite, or diaspore.

In Fig. 9, the thermal curves of the various clays are quite characteristic, giving distinct heat-absorption peaks for kaolin, diaspore, and gibbsite. Even when the peaks for diaspore and kaolin occur together, it is possible to resolve the separate peaks readily to determine their relative areas. Of particular interest is the distinct difference in the thermal curve for the Georgia bauxite and the Missouri diaspore, although the chemical analyses of the two are nearly identical. It would, perhaps, be well to confine the term "bauxite" to mixtures of kaolin and gibbsite and the word "diaspore" to the pure mineral or to its mixture with kaolin.

In Table VI, the areas under the various peaks for these clays are tabulated, and these areas are then

TABLE VI

Material	Area of kaolinite peak (sq. in.)	Area of diaspore peak (sq. in.)	Area of gibbsite peak (sq. in.)	Kaolinite by area (%)	Diaspore by area (%)	Gibbsite by area (%)	Free silica and inert material (%)	Al_2O_3/SiO_2 by area	SiO_2 (%)	Al_2O_3 (%)	TiO_2 (%)	Fe_2O_3 (%)	Combined H_2O (%)	Al_2O_3/SiO_2 (%) (by analysis)
Semiflint (Mo.)	0.45			82			18	0.61	54.5	30.2	1.9	2.2	10.2	0.55
First-grade diaspore (Mo.)		0.55			90		10	7.4	10.9	72.4	3.2	1.1	13.5	6.63
Bauxite (Ga.)	0.37		0.40	67		38		1.95	32.0	65.0				2.02
Burly flint clay (Mo.)	0.39	0.16		71	26		3	1.32	33.8	49.4	2.6	1.8	12.0	1.46
Second-grade diaspore (Mo.)	0.10	0.32		18	53		28	1.41	29.2	53.3	2.7	1.9	12.0	1.82
Hard flint clay (Mo.)	0.64			100*				0.84	46.0	36.0	3.3	1.3	13.5	0.78

* Based on 0.64 area for compacted kaolinite.

converted to percentages by dividing by the area of the peak for the pure material and multiplying by 100. The ratio of alumina to silica is then computed from these percentages, considering the inert matter to be principally silica. This, however, is not entirely correct because it does contain some iron and titanium minerals, and it is not known how much of them is in the crystal lattice of the clay minerals. The Georgia bauxite gives a total kaolinite and diaspore percentage of 105%, which is simply an error in the quantitative measurements.

The chemical analyses of these clays are also given in Table VI, and the alumina-silica ratio is computed from them. In general, it will be found that a surprisingly good agreement exists between the two.

VII. Conclusions

It would seem that the thermal method will be found particularly valuable to identify clay minerals when they occur either in such a finely crystalline state that the petrographic method is of little value or where they occur in mixtures in which the X-ray identification is difficult. The thermal method, of course, will not supplant either of these other methods, but in conjunction with them, it will permit increased ability to determine the clay minerals with certainty. An example of this is the identification of clay minerals in the reaction product of feldspar treated in a pressure chamber. The minerals were finely crystalline and a number of them occurred together so that the X-ray method did not give a very clear picture. The thermal method, however, confirmed the results from the X-ray qualitatively, and gave more or less quantitative results as to the amounts of the various minerals.

The thermal method should also be of considerable value as a control of raw material, particularly in connection with the high alumina clays which are becoming so important in the refractories industry. A thermal curve can be obtained much more quickly and at less expense than a chemical analysis, and in some ways it will give more definite information as to the type of clay. It is believed that a thermal analysis apparatus should be a part of every research and control laboratory dealing with clays.

Acknowledgments

The author wishes to express his thanks especially to Dr. Ross of the U. S. Geological Survey for his interest in this problem, which could not have been carried out without his coöperation in supplying the pure minerals. Thanks are also due to Professor Kerr of Columbia University, who was able to supply the rare mineral, nacrite, for this work, and to Dr. Insley of the Bureau of Standards, who was helpful with advice and suggestions on this problem.

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February, 1939
18—2

Abrasives

Controlling quality of abrasives by X-rays. I. Terminasov and L. Kharson. *Vestnik Metalloprom.*, **17** [9] 2–5 (1937).—The authors examined various abrasives, *e.g.*, corundum, silicon carbide, etc., to discover internal defects. The abrasives used were of different preparations, forms, and thickness. By means of X-rays (visual method on translucent screen) it is possible to distinguish clearly the following internal defects: (1) empty shells from 1.5 m. in diameter to any large dimension, (2) shells filled with mellow abrasive materials, (3) diverse internal fissures of various lengths, widths, and directions, (4) metallic inclusions in the material of the abrasive, and (5) inhomogeneous density of the material of the abrasive. The X-ray control was effected by means of high tension Roentgen apparatus. The maximum of high tension on the X-ray tube was 200,000 v. X-ray control of a disk 600 mm. in diameter and 60 mm. thick was reduced to 4 to 5 sec. If the abrasive is more than 600 mm. in diameter, it can be controlled in two operations. By using 220,000 v. on the X-ray tube, the internal defects of an abrasive 80 mm. in thickness can be distinguished. In plants, the X-ray apparatus should be used (1) before firing the abrasive to control the moist disk and (2) after the firing. X-ray control is recommended as a simple, convenient, and rapid method of distinguishing internal defects. B.E.K.

Future of the abrasive industry. Howard W. Dunbar. *Iron Age*, **142** [13] 39–40 (1938).—D. gives brief notes on the development of grinding and general comments on the progress of the industry. E.H.McC.

Grinders predominate in machine tool developments. Frank J. Oliver. *Iron Age*, **141** [6] 31–37 (1938).—O. briefly describes new equipment including a few types of grinders. *Ibid.*, **142** [19] 50–55A (1938).—Several commercial grinders are described and illustrated. E.H.McC.

Portable grinders—examples of varied applications. G. H. Nehoda. *Can. Machinery*, **40** [11] 16, 57, 59 (1938).—Applications of portable grinders to the manufacture of automobile tire pump equipment, die and pattern making, valve grinding, milling machines, and precision grinding are enumerated and illustrated. D.A.B.

PATENTS

Abrasive. N. P. Robie (Carborundum Co.). U. S. 2,138,882, Dec. 6, 1938 (July 27, 1936). A coated abrasive has a backing comprising a woven glass fabric, a heat-hardened adhesive, and a layer of abrasive grain attached to the backing by means of the adhesive.

Abrasive article and its manufacture. J. A. Boyer (Carborundum Co.). U. S. 2,137,200, Nov. 15, 1938 (June 28, 1937). An abrasive article consists of abrasive comprising diamonds and a sintered bond therefor composed principally of aluminum and containing, in an aluminum base alloy, a hardening agent consisting of an intermetallic compound of aluminum and another metal, in such an amount as to harden the bond but not to destroy its ductility.

Abrasive article and its manufacture. J. A. Boyer (Carborundum Co.). U. S. 2,137,201, Nov. 15, 1938 (June 28, 1937). An abrasive article consists of abrasive material comprising diamonds embedded and dispersed in a sintered metal matrix consisting principally of a ductile silver-base alloy which alloy contains as a hardening agent at least one metal other than silver retained in solid solution, in such an amount as to harden the matrix but not to destroy its ductility.

Abrasive article and its manufacture. J. A. Boyer (Carborundum Co.). U. S. 2,137,329, Nov. 22, 1938 (July 6, 1937). An abrasive article comprises diamonds and a sintered metal bond consisting principally of a ductile copper base solid solution containing between 5 and 15% tin.

Abrasive article and method of making. J. N. Kuzmick and L. S. Hilton. Brit. 494,641, Nov. 9, 1938 (Feb. 11, 1938).

Apparatus for shaping grinding wheels. W. H. Newman. Brit. 494,704, Nov. 9, 1938 (June 25, 1937).

Buffing wheel. Joseph Levoy. U. S. 2,136,747, Nov. 15, 1938 (Oct. 25, 1937).

Crankshaft grinding apparatus. A. J. Sievers, Jr. (E. W. Oliver and P. E. Gooch). U. S. 2,138,258, Nov. 29, 1938 (Feb. 6, 1937).

Cutting or grinding equipment. H. J. Perazzoli. U. S. 2,137,306, Nov. 22, 1938 (March 6, 1936).

Device for truing grinding wheels. W. C. Fairweather (B. G. La Bougie). Brit. 494,471, Nov. 9, 1938 (Jan. 10, 1938).

Grinder workstand. Martin Hokanson (Eidco, Inc.). U. S. 2,136,616, Nov. 15, 1938 (Oct. 26, 1936).

Grinding equipment. H. J. Perazzoli. U. S. 2,137,305, Nov. 22, 1938 (Oct. 1, 1935).

Grinding machine. R. A. Cole (Norton Co.). U. S. 2,137,644, Nov. 22, 1938 (March 26, 1936). H. W. Dunbar and H. S. Indge (Norton Co.). U. S. 2,137,821, Nov. 22, 1938 (May 12, 1937).

Grinding screw threads. F. Forg (trading as P. Forg & Co.). Brit. 494,986, Nov. 16, 1938 (Oct. 5, 1936).

Grinding tool. A. J. Sievers, Jr. (E. W. Oliver and P. E. Gooch). U. S. 2,138,257, Nov. 29, 1938 (April 21, 1936). A device for grinding an exterior surface comprises a member adapted to rotate around the surface, a grinding element carried by the member and engageable with the surface, and means operated by the friction of the element on the surface upon rotation of the member to urge the element against the surface.

Grinding-wheel dresser. H. W. Kropf (Brickner-Kropf Machine Co.). U. S. 2,137,690, Nov. 22, 1938 (Aug. 15, 1938).

Knife sharpeners with rotating disks. Industrie Akt.-Ges. Allegro. Brit. 495,351, Nov. 23, 1938 (Nov. 12, 1936).

Machine for grinding and finishing cylinders. K. W. Connor (Micromatic Hone Corp.). U. S. 2,138,535, Nov. 29, 1938 (Sept. 12, 1935).

Making abrasive articles. R. C. Benner and G. J. Easter (Carborundum Co.). U. S. 2,136,931, Nov. 15, 1938 (Sept. 11, 1937). The process of manufacturing metal-bonded abrasive articles comprises coating non-metallic abrasive particles with an amalgam, thereafter mixing the amalgam-coated particles with a metal powder free from mercury to form an abrasive mixture, and forming and sintering the mixture.

Making a composite abrasive wheel. Baalis Sanford (Norton Co.). U. S. 2,137,986, Nov. 22, 1938 (Jan. 12, 1937).

Manufacture of bonded abrasive articles. R. C. Benner and Peter de Leeuw (Carborundum Co.). U. S. 2,138,829, Dec. 6, 1938 (July 9, 1936). A bonded abrasive article comprises aluminous abrasive grain and a binder comprising the hydrothermal reaction products of CaO, SiO_2, and Al_2O_3.

Metalworking machine. E. S. Cornell (Abrasive Machine Tool Co.). U. S. 2,136,491, Nov. 15, 1938 (Jan. 11, 1937).

Polishing or grinding roll. H. H. Giles (D. T. Giles). U. S. 2,139,406, Dec. 6, 1938 (Dec. 22, 1936).

Polishing machine. C. T. MacLean (Motor Products Corp.). U. S. 2,137,535, Nov. 22, 1938 (May 27, 1936).

Production of abrasive articles. R. C. Benner and Peter de Leeuw (Carborundum Co.). U. S. 2,138,830, Dec. 6, 1938 (July 27, 1936). A bonded abrasive article comprises abrasive grain and the hydrothermal reaction product of CaO, SiO_2, and Al_2O_3.

Producing and/or finishing screw threads by grinding. S. J. Harley. U. S. 2,138,739, Nov. 29, 1938 (Nov. 21, 1935).

Radial grinder. John Lewis. U. S. 2,137,140, Nov. 15, 1938 (March 7, 1938).

Surfacing machine. H. L. Trimble (H. C. Trimble). U. S. 2,136,529, Nov. 15, 1938 (Jan. 12, 1934).

Art and Archeology

Chinese wine pot with colored glazes. *Connoisseur*, **102** [447] 226 (1938).—Full-page color illustration. This 17th Century wine pot has a turquoise body with streaks of aubergine and yellow; height 6 in. The Lady Lever Art Gallery. M.E.P.

Ching, the potter. John A. Foster. *Bull. Amer. Ceram. Soc.*, **17** [12] 491–93 (1938).

Coloring of Chinese porcelain. Frank Davis. *Illus. London News*, **103** [2673] 112 (1938).—D. discusses the value of the color of Chinese porcelain, with special notation on the difference between *Famille Verte* and *Famille Rose*. Illustrated. L.F.M.

Eighteenth-century chandeliers at Bath. J. Bernard Perret. *Connoisseur*, **102** [446] 187–92 (1938).—The restoration of the assembly rooms at Bath brought to light interesting facts about the origin of the cut-glass chandeliers which have hung there 170 years and about the history of the glassmaking industry of the 18th Century. The glass was previously called "Waterford" because of the brilliant metal and dark color long associated with that factory, but these are caused by chemicals used in the manufacture and are common to all good quality glass made during this period. The fact is disclosed, however, that the Irish factory was founded in 1783, while the assembly rooms were opened in 1771. One of the chandeliers bears a beautifully engraved inscription of "Parker, Fleet Street, London." The records of the glass industry show that the glass used by Parker probably came from the Whitefriars Glassworks just around the corner from the Fleet Street address. These Bath chandeliers are in the rococo style, and different designs were used in the various rooms. A strong resemblance to a smaller Waterford chandelier in the Victoria and Albert Museum may indicate that Irish factories copied designs that were popular in London 20 years before. Illustrated. M.E.P.

Equestrian figure in Staffordshire ware of William III depicted as a Roman emperor. *Connoisseur*, **102** [446] 170 (1938).—Full-page color illustration of a figure by Ralph Wood; height 15 in. This is one of two extremely rare examples in the Mackintosh collection. See "Early English pottery figures—," *Ceram. Abs.*, **18** [1] 4 (1939). M.E.P.

Faenza and the origin of white faience. D. Chompret. *Céram., Verrerie, Email.*, **6** [5] 165–72; [6] 199–202 (1938).—The origin and spread of white faience are discussed. Originated at Faenza about 1570 by the artist Virgilioto Calamelli, called Mercadet, it was a reaction against the excessive decoration and the abuse of richness of ceramics in vogue in Italy. It was known as the "compendiario" style or style of simplification and consisted of a white faience decorated more or less summarily. Beauty of form and especially the whiteness and purity of the enamel gave the piece its value. A subject, such as a personage, coat of arms, etc., drawn with a fine stroke in blue, occupied the center of the piece, and not far from the edge was a very small wreath of little flowers, volutes, or vine leaves; a few touches of yellow in two tones and sometimes a little pale green enriched the sketch. This style was very successful, and it democratized faience since great artists were no longer needed and everyone could afford to buy it. Before it appeared, the sumptuously decorated faience ware had been used only as show pieces of the wealthy. The simplified style spread throughout other countries, adopting a particular character according to each region and being transformed by new influences; this is regrettable from an artistic standpoint but important for humanity in general. M.V.C.

Hellenic influence on Chinese ceramic art. Anon. *Illus. London News*, **102** [2661] 710 (1938).—Many examples of Chinese ceramic art, dating from A.D. 618, appear to be patterned after drinking cups of the Mediterranean area. They are made of cream or reddish pottery and are covered with green or amber-colored glaze. The form is usually an animal's head or curved horn. Illustrated. L.F.M.

Index of American design. Anon. *Design*, **40** [3] 4 pp. (1938).—A working outline of what is to be found in the portfolios of native arts soon to be published includes

(1) New Jersey: Caspar Wistar's Salem County glass of 1739 and the Stenger glass from the factory in Glassboro; (2) New York: the rare glass made at Redfield; (3) Ohio: the largest known authentic collection of pottery (that of the Historical Society in the Public Library in East Liverpool) whose portfolios will be divided into four groups, *viz.*, earthenware, salt-glazed stoneware, Upper Muskingum Valley pottery lamps, and miniature examples of pottery; (4) Pennsylvania: a group of four tile with biblical designs in purple line on white ground by Stiegel of Manheim which is unique; (5) Utah: ceramics, crude but serviceable. See *Ceram. Abs.*, **18** [1] 5 (1939). M.E.P.

Pottery of ancient Honduras. MOYNE. *Illus. London News*, **102** [2665] 916–19 (1938).—Examples of ancient Honduras pottery are numerous. Whistles, vessels, and hollow ware are fashioned in human and animal form. Illustrated. L.F.M.

Pottery from Persia. S. SMITH. *Brit. Museum Quart.*, **12** [4] 140 (1938).—Three grayware pots from North Persia (now in the British Museum) which may belong to the early second millenium are briefly described and illustrated. A.B.S.

Roman glassware found in the Rhineland. ANON. *Illus. London News*, **102** [2658] 588 (1938).—Workmen near Kretz uncovered a limestone coffin containing seven vessels of blue-green glass, three of earthenware, and a terra cotta figure. The glass pieces, ranging from 3 to 11 in. in height, are perfectly preserved and of excellent workmanship. Illustrated. L.F.M.

Rose in art. ANON. *Céram., Verrerie, Email.*, **6** [6] 195 (1938).—An exposition of the rose in art has been assembled at the Chateau de Bagatelle. It consists of the most beautiful works of art inspired by the rose, including sculpture and ceramics. The porcelains of Sèvres and the faience of Marseilles and Strasbourg have exploited this motif. M.V.C.

Scarlet Ware. ANDRÉ PARROT. *Illus. London News*, **102** [2666] 954 (1938).—From the Royal Tomb at Mari, Mesopotamia, two examples of Scarlet Ware, dating from 3000 B.C. were recovered. Illustrated. L.F.M.

Seventh National Ceramic Exhibition. ANON. *Bull. Amer. Ceram. Soc.*, **17** [12] 482–84 (1938); *Design*, **40** [4] 3 pp. (1938).—Prize awards of the Robineau Memorial Exhibition at the Syracuse Museum, from which 100 pieces will be chosen for the Golden Gate International Exposition in 1939, are described. Two hundred ceramists from the U. S., Honolulu, and Canada entered 1513 pieces. A complete list of the jury and the award winners is given. Illustrated. M.E.P.

Six enamels by the master "KIP." MARVIN CHAUNCEY ROSS. *Connoisseur*, **102** [446] 182–84 (1938).—The 16th Century enamelers of Limoges are not so well known as the majolica painters of Italy, although their influence on the Renaissance in France is undisputed. The enamels by the master KIP in the Walters Art Gallery show his excellent craftsmanship and mastery of the medium. H. P. Mitchel, noted art historian (in "Who was the Limoges enameler 'KIP'?" *Burlington Mag.* (1909)), advanced with new evidence the theory of A. Franks that KIP was a pseudonym for Jean Poillèvé, a member of an artistic Limoges family and a goldsmith (enamelers were generally referred to thus in Limousin) between 1537 and 1559. Several of the designs on the enamel plaques in the Walters Art Gallery were derived from contemporary prints or bronze plaquettes. All of them are in grisaille with gilded details and show great technical skill. Illustrated. M.E.P.

Staffordshire earthenware busts representing King George III and Queen Charlotte. *Connoisseur*, **102** [446] 205 (1938).—Full-page illustration in color of two earthenware busts with translucent running glazes; Whieldon type, about 1761. Exhibited by J. R. Cookson at the Antique Dealer's Fair. M.E.P.

Würzburg Müller pitcher of 1684. H. KUHNERT. *Glastech. Ber.*, **16** [10] 322–24 (1938). J.F.H.

PATENTS

Decalcomania paper. LEWIS DAVIS (McLaurin-Jones Co.). U. S. 20,936, Dec. 6, 1938 (Dec. 8, 1937); reissue of original U. S. 2,023,803 (*Ceram. Abs.*, **15** [2] 53 (1936)).

Decorating ceramic objects. G. H. BURMEISTER. Swed. 91,466, Sept. 10, 1936. F.L.

Designs for:

Bottle. R. A. BLUNT. U. S. 112,272, Nov. 22, 1938 (March 11, 1938). U. S. 112,273 to 112,275, Nov. 22, 1938 (March 19, 1938). U. S. 112,276, Nov. 22, 1938 (March 29, 1938). U. S. 112,277, Nov. 22, 1938 (Aug. 27, 1938). W. R. KOHL (Carr-Lowrey Glass Co.). U. S. 112,462, Dec. 6, 1938 (April 22, 1938). F. N. LEWIS (Elizabeth Arden, Inc.). U. S. 112,464, Dec. 6, 1938 (June 11, 1938). O. H. SAMUELSON (Fairmount Glass Works, Inc.). U. S. 112,219, Nov. 15, 1938 (July 23, 1938). L. D. SOUBIER (Owens-Illinois Glass Co.). U. S. 112,385, Nov. 29, 1938 (March 17, 1938). G. F. STREET, JR. (Safeway Stores, Inc.). U. S. 112,387, Nov. 29, 1938 (July 24, 1937).
Compote bowl. R. R. KOSTELLOW (U. S. Glass Co.). U. S. 112,199, Nov. 15, 1938 (Feb. 15, 1938).
Deviled egg plate. A. J. BENNETT. U. S. 112,168, Nov. 15, 1938 (Aug. 26, 1938).
Glass bottle. L. J. KIHN (J. T. & A. Hamilton Co.). U. S. 112,198, Nov. 15, 1938 (March 23, 1938).
Goblet. A. J. CUNNINGHAM. U. S. 112,442 to 112,445, Dec. 6, 1938 (April 28, 1938).
Plate. R. R. KOSTELLOW (U. S. Glass Co.). U. S. 112,451, Dec. 6, 1938 (Feb. 9, 1938).
Tumbler. JEAN VIATOUR (Libbey Glass Co.). U. S. 112,164, Nov. 15, 1938 (Sept. 10, 1938).

Cements

Constitution of Portland cement. ANON. *Verre & Silicates Ind.*, **9** [5] 52–54 (1938).—The formation, structure, and mineral composition and the calculation of the free lime and the constituents of Portland cement are analyzed according to Lea and Desch ("Chemistry—," *Ceram. Abs.*, **15** [9] 267 (1936)). M.V.C.

Heat transmission in the cement rotary kiln. G. LINDBERG. *Tek. Tid.*, **68C** [3] 17–18 (1938).—L. calculates the quantities of heat required in the different parts of the rotary kiln and compares these figures with the ascertained area of the parts to obtain the amount of heat transmission. The figures are larger in the dissociation and water-evaporating zones than in the heating zone. F.L.

Enamel

Comparison of the tensile strengths of sheet-iron ground-coat enamel glasses. A. I. ANDREWS AND W. W. COFFEEN. *Jour. Amer. Ceram. Soc.*, **22** [1] 11–15 (1939).

Metal finishing processes—recent developments. FRANK J. OLIVER. *Iron Age*, **141** [9] 44–49 (1938).—A lengthy review of recent commercial apparatus includes brief notes on a sandblast gun, sandblast hose, centrifugal-blast abrasive cleaners, and a magnetic separator for enameling frits. E.H.McC.

Opaque porcelain cover coat developed. PORCELAIN ENAMEL & MFG. CO. *Steel*, **101** [13] 68 (1937).—A new superopaque sheet-iron cover coat showing high tear resistance and opacity has been developed. Tests showed 76.5% reflectance at 65 g. with 7% clay and no opaci-

fier. An addition of 4% tin oxide increases the reflectance 2½%. Warping is reduced to a minimum because the frit can be fired at a comparatively low temperature. H.E.S.

Properties of chilled metallic shot and grit used in sandblasting. J. E. Hurst and J. H. D. Bradshaw. *Foundry Trade Jour.*, **57**, 474–76, 508–10 (1937); *Iron & Steel Ind.*, **11** [6] 231–37 (1938).—Two important problems are the comparative values of (1) metallic and silica abrasives and (2) different kinds of metallic abrasives. Economy favors metallic grit, which has 10 to 20 times the life of sand; for some purposes, metallic shot has 60 times that of sand. In cleaning castings for enameling, one ton of chilled metallic grit usually does the same work as 16 tons of quartz. Certain records favorable to metallic abrasives show a reduction of 15 to 20% in air consumption and of 80% in wear of nozzles. Definite information is scarce. Chemical composition, hardness, strength, microstructure, specific gravity, and grading of metallic abrasives are discussed. H.E.S.+E.H.McC.

Vitreous enamel frits. G. H. McIntyre. Presented at meeting of Amer. Chem. Soc., Cleveland; abstracted in *Chem. Industries*, **42** [5] 521 (1938).—M. describes the functions of lithium, barium, beryllium, titanium, zirconium, fluorine, and cobalt in commercial enamel frits. P.G.H.

PATENTS

Agent for rendering enamels, etc., opaque. Soc. des Produits Chimiques des Terres Rares. Fr. 830,568, Dec. 9, 1937; *Chem.-Ztg.*, **62** [52] 746 (1938). D.A.B.

Apparatus for enameling articles of different measurements. Carl Thiel. Ger. 663,940, July 28, 1938 (Nov. 10, 1934); VI/48*c*. 7. Several feeders, a series of platforms for the material to be charged, are passed over each other in such a manner that each feeder or platform runs by each of the work or loading places provided for working the different work pieces. D.A.B.

Charging device for a firing oven. Emaillierwerk Krone Raestrup & Co. Ger. 660,782, May 12, 1938 (June 10, 1936); VI/48*c*. 7. A charging device for a firing oven is designed with vertical upward and downward movement of the supporting arms of the charge; the lifting device is designed as an articular quadrangle which is attached to both sides of the frame; it supports the carrying arms and is in union with the part conducting the lifting power over an intermediate transmission. Ernst Schroeder (Emaillierwerk Krone Raestrup & Co.). Ger. 662,043, June 9, 1938 (March 27, 1937); VI/48*c*. 7. The side pieces of each articular quadrangle are flexibly divided. D.A.B.

Enameling furnace. J. C. Woodson (Lee Wilson Sales Corp.). U. S. 2,137,040, Nov. 15, 1938 (Aug. 11, 1937).

Method and apparatus for granulating porcelain enamel. H. E. Craven, Jr., and F. K. Knudsen (Porcelain Enamel & Mfg. Co.). U. S. 2,137,931, Nov. 22, 1938 (June 9, 1936).

Platelike hearth lining for electric resistance ovens, especially enameling ovens. Brown, Boveri & Cie, A.-G. Ger. 660,719, May 12, 1938 (Aug. 28, 1926); VI/48*c*. 7. The hearth lining is designed with supports which are rigidly joined to the lining and which serve to hold the interchangeable firing rods. D.A.B.

Production of white clouded enamels on iron. I. Kreidl. Brit. 494,799, Nov. 16, 1938 (Nov. 11, 1936).

Smelting enamel. R. H. Türk (Porcelain Enamel & Mfg. Co.). U. S. 2,137,930, Nov. 22, 1938 (May 14, 1931; renewed July 28, 1936).

Spraying molten pulverized quartz or enamel mixtures. E. F. Callan. U. S. 2,137,442, Nov. 22, 1938 (Sept. 27, 1935). A method of spraying molten pulverized coating mixtures consists in producing a substantially circular blow flame within a chamber having an outlet opening directly in front of and in alignment with the flame, causing the pulverized coating mixture to flow axially through the circular blow flame so that it is preheated by the heat developed by the blow flame within the chamber, causing the preheated pulverized mixture to flow with the circular blow flame through the chamber toward the outlet opening, so as to melt the pulverized coating mixture and causing it, in molten condition, and the circular flame to discharge through the outlet opening so that the molten mixture is delivered directly onto the surface to be coated.

Supporting structure for porcelain enameled pans. J. H. Miner (Roesch Porcelain Construction, Inc.). U. S. 2,139,322, Dec. 6, 1938 (May 29, 1937).

Glass

Absorption changes in ultra-violet transmitting glasses. W. Dusing and A. Zincke. *Glastech. Ber.*, **16** [9] 287–92 (1938).—Glasses were prepared from purified batch materials containing a maximum of 0.0005% Fe_2O_3 and 0.0005% TiO_2. Transmission curves on a soft Na_2O, B_2O_3, SiO_2 glass and a hard Na_2O, K_2O, Al_2O_3, B_2O_3, SiO_2 glass with various amounts of Fe_2O_3 and TiO_2 are in agreement with the literature in regard to the effect of Fe_2O_3 and TiO_2. Transmission changes due to aging by irradiation with a Hg light, however, do not appear to be connected with iron content. The percentage of change in transmission by aging of the hard glass was practically the same with Fe contents of 0.01% and 0.0003%. In the case of the soft glass, the change of transmission was greatest with the lowest iron content. Pure SiO_2 and B_2O_3 glasses are scarcely affected by aging. The transmission of a GeO_2 glass dropped from 75% to about 55% at 3000 Å with the same treatment. A study of simple binary glasses showed that irradiation increases the transmission for shorter wave lengths, the initial and final curves crossing between 2000 and 3000 Å. Qualitatively, alkali and alkaline-earth silicates are similarly sensitive to ultra-violet radiation. Quantitatively, the alkali silicates are more sensitive. There is little difference between K and Na glasses. By use of monochromatic radiation it was shown that radiation above a wave length of 2300 Å has practically no effect on unradiated glass; it does, however, regenerate previously aged glasses. Radiation at a wave length of about 2000 Å is active in causing transmission changes. J.F.H.

Air conditioning. George W. Meek. *Mill & Factory*, **23** [3] 66–70, 170 (1938).—Glass block replace windows in the air-conditioning scheme of the Carrier plant. The plan is described and illustrated. D.A.B.

Annealing glass. C. Deneuville. *Céram., Verrerie, Email.*, **6** [7–8] 217–23 (1938).—When hot glass is being worked, the surface of the glass is sometimes suddenly cooled by air or contact with metallic pieces and becomes a seat of ultra-microscopic fissures (Peddle). The interior cools more slowly because of the low conductivity of glass; the external layers are solidified while the interior continues to contract. Because of the solidarity of the different layers when the object is entirely cooled, the peripheral parts are in compression; conversely, the interior, which is thwarted in its contraction of thermic origin, is subjected to extension. Glass resists compression 17 times better than it resists extension, and, as the surface which is particularly exposed to shocks is in compression, certain advantages are found (in hardened glass, safety glass); the presence of these tensions, however, is a great disadvantage in optical glass and other cases where they must be reduced or eliminated entirely. An examination of the behavior of glass on cooling shows a point of transformation above which the glass is more or less liquid and below which the viscosity is great and the glass becomes elastic. This point is not defined with great precision; it varies with the chemical composition of the glass and probably with the anterior treatment undergone. There are two types of tensions: (1) temporary tensions which do not exceed the elasticity limits and therefore do not endanger sta-

bility, occurring during the final stages of cooling, and (2) permanent tensions which affect the stability of the object. The purpose of annealing is therefore to reduce entirely or partially the permanent tensions and to cool the glass so that temporary tensions do not cause rupture. Tensions can be observed by polariscope and measured in simple cases. The speed of relaxation of a tension at constant temperature is proportional to the square of that tension (Adams and Williamson, whose mathematical theory is given). The annealing temperature zone is generally agreed to lie between (1) a low temperature below which a permanent tension can no longer be removed or further permanent tensions formed and (2) an upper temperature limit above which tensions disappear. In practice, the latter point is limited by the danger of deformation, devitrification, and the adherence of objects. The temperature interval between these points, known as the zone of relaxation, shifts according to the composition of the glass. The upper temperature limit is raised considerably by Ca, less by MgO, and much less by ZnO, while PbO and BaO have little effect (English and Turner). The lower temperature limit corresponds to a viscosity of 10^{13} poises. According to recent theories, a transformation point or critical zone of the passage from the viscous state to the solid state should occur here. The annealing point, according to Lillie, is the temperature at which the birefringence of a cylindrical rod 4 cm. in length disappears in 15 min. For all glasses the viscosity is 2.5×10^{13} poises. The temperature is evidently a function of the chemical composition. The upper temperature limit coincides more or less with the softening temperature defined by Littleton, *i.e.*, the temperature at which a thread of glass 1 mm. in diameter and 10 cm. long lengthens 1 mm./min. by the action of its own weight. Between the upper and lower temperature limits, the temperature fall per unit of time must not exceed a maximum; otherwise new permanent tensions are created. Below the annealing point, cooling may proceed rapidly because only temporary and usually harmless tensions are formed. Tensions are present in annealed glass because (1) the annealing temperature was too low or the lower temperature limit was not surpassed or maintained long enough; or (2) reheating approached the upper temperature limit but cooling was too rapid. Residual tensions are always found in commercial glasses. Chemical reactions sometimes occur on the surface of glass in contact with combustion products during annealing. Progress in perfecting annealing furnaces and technique is described. M.V.C.

Antimony sulfide ruby glasses. A. DIETZEL. *Glastech. Ber.*, **16** [10] 324–28 (1938).—Melts were made from a soft glass of the composition SiO_2 34, Na_2O 18, and Ca 8% with systematically varied amounts of Sb_2O_3, S, and C. The chilled melts were usually bright yellow or brownish. A definite degree of reduction is necessary in melting to produce a glass that can be colored by warming in. With too little reduction the sulfides are unstable, and with too strong reduction metallic Sb results. The lower limit of Sb_2O_3 to produce color is 0.5 to 0.8%. Warming in of suitably composed glasses results in a deep red color due to Sb_2S_3, which separates out. Coloring with the compositions studied sets in noticeably at 580°C. This is appreciably higher than the temperature required by a copper ruby glass of similar composition. The absorption spectrum is similar to that of other ruby glasses. The solubility product of Sb_2S_3 in the glass at 600 to 800°C is estimated as 5×10^{-4} from analytical data. The tendency to liver is less at medium than at very small concentrations. J.F.H.

Base release of some commercial glasses as determined by electrodialysis. R. M. KING. *Jour. Amer. Ceram. Soc.*, **22** [1] 8–10 (1939).

Behavior of sulfur, selenium, and tellurium in glass. A. DIETZEL. *Glastech. Ber.*, **16** [9] 292–96 (1938).—An extensive analogy exists between the behavior of these elements in glass and that in aqueous solutions in regard to oxidation state. They may be present in glass as (1) sulfide, etc., (2) polysulfide, etc., (3) free element, (4) sulfite, etc., or (5) sulfate, etc. The sulfur is strongly electronegative, while tellurium is of a more electropositive character. The formation of poly-compounds depends greatly on the alkalinity and partial O_2 pressure in the melt. The sensitiveness toward O_2 in lower states of oxidation increases from S to Te. Free sulfur is formed in relatively acid glasses, where polysulfides are unstable. Free Se is formed under less acid conditions and Te under still less acid conditions. Free sulfur in glass produces a blue color. Comparison of fluorescence spectra with those of ultramarine indicates a molecular dispersion rather than a colloidal dispersion of the sulfur. A similar condition exists with selenium in the case of the pink selenium color. Tellurium is too strongly electropositive to be kept in solution. It forms colloidal droplets and rapidly separates out. J.F.H.

Ceramics and glass at the Leipzig fair. ANON. *Keram. Rundschau*, **46** [16] 177–79 (1938).—New applications of glass, hard porcelain, and tile are described. F.B.V.

Changes caused by radiation in quartz and various glasses. J. HOFFMANN. *Glastech. Ber.*, **14** [8] 281–86 (1936).—The varying behavior toward radiation of quartz varieties among themselves and comparison with that of purest precipitated SiO_2, which is not affected, show that radiation changes in quartz and quartz glasses are associated with structure characteristics not present in the pure precipitated SiO_2. The favorable effect of strong heating on color formation indicates that the cause is to be looked for in some of the transformations which quartz undergoes. In a simple silicate glass containing TiO_2, radiation causes the formation of violet-colored Ti_2O_3, apparently without accompanying reducing action on the SiO_4 structure. The evolution of H_2 through the action of alkali is detectable by microchemical means on irradiated brown-colored samples. These effects are accounted for by a stepwise reduction to form Si at various places in the lattice. J.F.H.

Changes in the dispersion of optical glass in dependence on its thermal treatment. P. YA. BOKIN. *Optiko-Mekh. Prom.*, **7** [12] 4–6 (1937); abstracted in *Chem. Zentr.*, **1938, II**, 2009.—The measurement of 24 specimens of 7 types of glasses showed that in the range of the visible spectrum (about 4000 to 7000 Å) a change of the coefficient of refraction of about 276×10^{-6} due to the thermal hardening corresponds to a similar change of the dispersion of 0.8×10^{-6}. M.V.C.

Changes in the viscosity of glasses in the range of the annealing temperature. A. S. GORALNIK AND K. S. EVSTROP'EV. *Optiko-Mekh. Prom.*, **7** [10] 10–14 (1937); abstracted in *Chem. Zentr.*, **1938, II**, 2009.—According to the process of Lillie (*Ceram. Abs.*, **11** [5] 298 (1932); *Jour. Amer. Ceram. Soc.*, **15** [8] 418–24 (1932); **16** [12] 619–31 (1933)) the viscosity was determined for optical glasses in the temperature ranges 360° to 540°, 500° to 760°, and (for two glasses) 600° to 1300°. Parabola-formed curves were obtained. The measuring results agree well with values calculated according to the equations of Waterton and Tammann. M.V.C.

Chemical stability of glasses: II. W. GEFFCKEN AND E. BERGER. *Glastech. Ber.*, **16** [9] 296–304 (1938).—Glass samples consisted of plates 1 x 22 x 16 mm. The polished samples were clamped in a silver frame with a rubber sheet to protect the surfaces except for a 7 x 6 mm. area in one corner. The samples were then exposed to chemical attack by the solution being considered, and the decrease in thickness of the exposed glass area was determined by a Haber-Lowe interferometer. This method has definite advantages over the powder method in that it is independent of the magnitude of surface, changes in concentration of the solution, and a knowledge of the glass composition or density. In the case of alkaline attack with alkali, alkali carbonate, or secondary phosphate, all of the glass is removed, and there is a direct proportionality between attack and time for various concentrations at 100°C. The rate of attack becomes independent of stirring at relatively slow speeds. The dependence of alkali attack on concentration is expressed well by Langmuir's adsorption isotherm. The dependence of velocity of attack on temperature follows the Arrhenius

law $v = A \times e^{-Q/RT}$, where v = depth of glass removed per hour (in μ/hr.), A = the action constant (in this case 10^{11} to $10^{9.5}$), and Q = activation energy. The value of Q is practically constant for all the glasses examined and averages 18.5 cal. Results by this method are in agreement with results by the Weber and Sauer method (weight loss of plates) but vary widely from results of the powder method, the latter being noticeably affected by the dissolved glass constituents. The accuracy of the interferometer measurement is $+0.02\mu$. The poisoning effect of glass constituents on velocity of attack is shown quantitatively for a barium crown glass in NaOH by plotting the ratio of velocity in the poisoned solution to velocity in pure alkali against concentration of dissolved glass in grams per liter. The effect is most marked in the lowest concentrations and varies greatly for individual glasses. The attack of alkalis is viewed as taking place in two steps. First, an extraordinarily fast OH^- adsorption equilibrium is established at the interface with formation of loose adsorption compounds. The adsorption compound breaks up when sufficient activation energy is supplied with the rupture of a Si-O-Si linkage in the glass. This process is slow up to 100°C; it is the controlling factor, therefore, and diffusion effects are secondary. The poisoning effect is then a change in the OH ion adsorption equilibrium resulting from simultaneous adsorption of other ions. For Part I see "Principles—," *Ceram. Abs.*, **17** [1] 13 (1938). J.F.H.

Control of raw materials for the glass industry. C. DENEUVILLE. *Céram., Verrerie, Email.*, **6** [6] 186–88 (1938).—The composition, harmful impurities, and accessory components of sand, lime, minium, soda, and potash used in making glass are given. M.V.C.

Decoloration of glass. C. DENEUVILLE. *Céram., Verrerie, Email.*, **6** [5] 145–47 (1938).—The mechanism of decoloration as explained by Jebsen-Marwedel ("Technology—," *Ceram. Abs.*, **16** [1] 16 (1937)) and Jaeckel is discussed. Chemical reactions taking place in the transformation of the undesirable coloring substance, *e.g.*, iron, into volatile or colorless or less intensely colored material are discussed, and the explanation of Löffler (*ibid.*, **11** [10] 521 (1932)) is given. Physical decoloration with selenium, nickel, cobalt, and neodymium is explained. The aim is to obtain a neutral gray with an accompanying loss of transparency by the addition of a complementary coloring; this treatment usually follows chemical decoloration for purposes of correction. M.V.C.

Defects in glass. F. H. ZSCHACKE. *Glashütte*, **68** [26] 440–42 (1938).—The importance of technical literature in combating defects is shown. M.V.C.

Determination of the density of glasses by the law of addition. P. BARY AND J. HERBERT. *Compt. Rend.*, **207** [15] 627–29 (1938).—The density of a glass can be calculated correctly from its constituents only if the densities of the constituents are introduced for the state in which they are present in the glass, *e.g.*, the density of silica in the quartz state is 2.65, while in the amorphous state it is 2.20. On the basis of the previously developed theory that a glass is a frozen product formed of dissolved alkaline silicates in alkaline-earth polysilicates, silica in glasses takes two distinct forms, crystalloidal and vitreous. By applying to each the proper specific gravity, a calculation was made of the density of various glasses which agreed with the measured density very closely. M.H.

Development of the photographic lens. R. KINGSLAKE. *Sci. Jour. Roy. Coll. Sci.*, **7**, 111–20 (1937). N.M.S.

Fiber glass. J. H. PLUMMER. *Ind. Eng. Chem.*, **30** [7] 726–29 (1938).—Mechanical developments in the production of fiber glass are briefly described. Illustrated. F.G.H.

Fluorescence of glass. Qualitative data. P. GILARD, L. DUBRUL, AND D. CRESPIN. *Verre & Silicates Ind.*, **9** [22] 253–57; [23] 266–70 (1938).—In continuation of studies on the luminescence of glass (*Ceram. Abs.*, **17** [7] 247 (1938)), 1300 samples of known composition were examined by ultra-violet light from a 400-w. mercury-vapor lamp with fused silica casing and by Wood's light. Several series of systematically varied glasses were fused to establish optimum concentrations of certain elements, and the luminescence spectrums of several glasses were photographed. The actual observations scarcely permit important theoretical conclusions. The deductions relative to the mechanism of the fluorescence of glass could not be considered until after a photometric and spectral study. No observation appeared favorable to the opinion that the crystalline state is necessary to fluorescence. It is now possible to have a general idea of the influence of different constituents of the glass on its fluorescence. The complexity of this influence can be a valuable working instrument in certain studies, especially research which involves the knowledge of the degree of oxidation of different constituents (Pb, Mn, Cu) or the enlargement of certain isolated particles in the glass (Ag, Cu, CdS, mixed crystals CdS-CdSe, and probably sulfides). Fluorescence can be a useful and rapid instrument of control, especially in regard to decoloration by manganese. *Luminescence:* When radiant energy is absorbed by a substance, it can produce a chemical reaction, increase thermic agitation, or raise the atoms or molecules to a higher energy level; electrons are directed into an orbit distant from the nucleus; the molecules are thus in a critical and less stable state than originally and have a tendency to return to that initial state after a certain time in the excited state. The return of electrons to their primitive orbit is accompanied by an emission of light. The wave length of the emitted light is generally greater than that of the excitor radiation (Stokes' law). Formerly, the distinction between the two types of luminescence (fluorescence and phosphorescence) was based on the duration of the period of the excited state, whether emission ceased with the excitation or was prolonged afterward, but this was found an imperfect means of differentiation, although it is still used. Sometimes the molecules are so stable in their excited state that they do not return to their normal state after cessation of the excitation except when heated; this is the case with glasses where the coloration imparted by prolonged exposure to rays of short wave length (X, ultraviolet, radium) does not disappear until the glasses are heated almost to the transformation temperature. It is accompanied by an emission of light, called thermoluminescence or thermophosphorescence. Fluorescence exists when the molecule returns spontaneously to its initial energy state, and phosphorescence exists when an application of energy coming from the surrounding medium is necessary for the emission to be produced. Fluorescence is an intramolecular process, and phosphorescence is connected with ionization. The practical distinction between the types of luminescence is based on the action of the exterior energy. The intensity of phosphorescence decreases at low temperatures and increases when the temperature is raised; the duration of emission naturally varies inversely with its intensity. Conversely, the intensity of fluorescence does not change when the temperature is lowered. The effect on luminescence of the following materials is given: (1) Iron oxides: a slight fluorescence variable with the iron concentration was observed (0.1% gives a slight greenish glow); the optimum concentration is very small. A series of CaO-Na_2O glasses showed curious phenomena which are represented graphically. (2) Lead glasses: the complexity of phenomena is shown; it necessitates further study. (3) Chrome, nickel, and cobalt glasses: no fluorescence was found for Cr_2O_3 and NiO glasses. Cobalt glasses have a slight mauve fluorescence quite distinct from their proper color. With 0.01% CoO the glow is bluish green; optimum concentration seems to be about 0.005%. (4) Manganese glasses: complex phenomena exist, but optimum concentration appears to be high (about 2%). With 0.003% a slight olive fluorescence appears which turns to green, yellow, and then orange with higher concentrations (5%). The presence of oxidizer causes different and weaker tints. Fluorescence in manganese glasses presents an interesting study of the oxidation equilibriums in these glasses. The absorption permits only the estimation of the quantity of trivalent Mn, but the emission permits an evaluation of the quantity of divalent Mn; it has possible

usefulness in industrial practice. (5) Uranium glasses: nothing new was discovered. (6) Neodymium glasses: the intensity of the fluorescence increases up to 2% oxide. (7) Cerium glasses: optimum concentration is about 0.5% Ce_2O_3. (8) Gold glasses: a yellow-brown surface fluorescence appears which might also be produced by silver which was found to be always present. No conclusive evidence was found to attribute any fluorescence to glasses containing gold alone. (9) Copper glasses: complex fluorescence phenomena exist. The glasses change from dark green (2% Cu), to water green (0.5%), to yellowish green (0.2%), to greenish yellow (0.1%), and to yellow gold (0.05%); intensity increases with lower concentrations. As in manganese glasses, the fluorescence can be considered a useful indicator of the state of oxidation. Further research is required. (10) Silver glasses: little new was found. (11) Sulfur glasses: elementary sulfur gives a fluorescence of yellow, to orange, to brown and sometimes red, but the problem remains obscure. (12) Selenium glasses: as a new observation, a light brownish glow was seen in glasses fused in reducing conditions with elementary selenium. (13) CdSe-CdS rubies: glasses colored by selenium and cadmium sulfide show clearly a relation between absorption and emission similar to that in sulfur glasses. A review of literature on luminescence is given. M.V.C.

Sealing of metal leads through hard glass and silica. B. Jonas. *Phillips Tech. Rev.*, **3** [4] 119–24 (1938).—A survey is given of the sealing of metal leads through different kinds of glasses. The physical properties of various silicate glasses are presented in a table which is the best résumé of physical properties found in the literature. The two common kinds of metal-to-glass joints are noted: (1) the solid conductor is led directly through the glass, and (2) a thin metal edge seal is made with the glass, the conductor being led through this metal seal and not coming in contact with the glass; this method is quite complicated and is not satisfactory with glasses fusing at higher temperatures. J. discusses the technique and limitations of the first method. With soft glasses (range of expansion 80 to 110 $\times 10^{-7}$) this method is successful up to 20 amp., since metals with a coefficient of expansion which approximately matches that of the glass are available. With the so-called soft-hard glasses (expansion of 30 to 60 $\times 10^{-7}$), tungsten and molybdenum and Fe-Ni-Co alloys (American usage, Kovar) make fairly satisfactory seals. With harder glasses (expansion of 8 to 38 $\times 10^{-7}$), the stresses between the glass and the metal are too great for one seal. J. shows from calculations that, when the stresses found between the glass and the metal do not exceed the strength of the glass, a joint through the medium of a flux glass can be made fairly satisfactory. Such a seal, tungsten through fused silica by means of an intermediate glass of high melting point, is described and illustrated. It is claimed that leads carrying up to many hundred amperes may be made in this way. H.K.R.

Physical Properties of Silicate Glasses

	Group No.	Class	Sum SiO_2 and Al_2O_3 by weight (%)	Region where softening begins: Transformation point (°C)	Region where softening begins: Softening point (°C)	Coefficient of linear thermal expansion ($\alpha \times 10^7$)	Tensile strength (kg./mm.²)	Resistance to compression (kg./mm.²)	Heat conductivity (cal./cm. degrees sec.)	Electrical conductivity (T_k 100 °C)	Dielectric losses at 1.5×10^6 cycles/sec. $10^4 \tan\delta$	Transmissibility for ultraviolet of 1 mm. of glass at 3000 Å
Ordinary soft glass	(1)	Lead glass (alkali lead silicate glass)	35–65	380–500	420–600	85–95	3–7	50–90	0.017–0.037	250–380	8–80	
	(2)	Calcium glass (alkali calcium silicate glass)	65–75	470–530	550–600	80–110				130–300		0–75%
	(3)	Soft borosilicate glass (alkali borosilicate glass)	70–85	470–570	500–700	30–60	4–10 (15)	70–100	0.025–0.030	160–400	10–120	
Hard glass	(4)	Hard alumino-(boro) silicate glass poor in or free from alkali	75–95	650–900	750–1000	8–38	5–15	100	0.03*	350–600	10–30*	Up to 90%
		Quartz glass	100	1050	1300	5.5 to 6	>20(?)	>200	0.035	>600	2	92%

* Approximate.

about 150 people. The firm of George Davidson & Co. of Gateshead was founded in 1860, a year later than Turnbull's Glassworks. Pyrex brand ware is made by J. A. Jobling & Co. at Sunderland. The Lemington Glassworks has been a subsidiary of the General Electric Co. since 1906. Originally, these works had three large furnaces, erected in 1790 by the Duke of Northumberland; only one remains and it is not in use. Since 1918 the works have been making electric bulbs of all kinds and more recently glass tubing for neon signs. The latest innovation is the manufacture of cathode-ray tubes for television sets. Hartley, Wood and Co. is entirely a handcraft works for making colored glass of superior quality, suitable for stained-glass windows. Vitreosil products are made by the Thermal Syndicate, Ltd., at Wallsend. They are pure fused silica and are used for cooking and lighting ware, for industrial and scientific uses, and in electrical, optical, ultra-violet ray, and chemical work. A.B.S.

Glass substitute. V. E. Yarsley. *Times Trade & Eng.*, **44** [897] 52 (1938).—Cellulose acetate is being increasingly used in place of glass for milk bottles, but the cost is still too high for its extended use. Glass is very inexpensive, and the average life of a glass milk bottle is twelve deliveries. A.B.S.

Glasslike but springy. Anon. *Gen. Elec. Rev.*, **41** [10] 462 (1938).—A short description is given of clear, glasslike, fused-quartz springs which are made of hairlike filaments; they may be stretched to ten times or more their original length and will return exactly (steel springs would undergo a permanent stretching). Such springs can be used at high temperatures where steel springs would lose their temper. Other advantages are cited. L.E.T.

Glassmaking in Northumberland and Durham. Anon. *Times Trade & Eng.*, **43** [896] 28 (1938).—Most of the Northeast Coast glassworks were established when small sailing ships carried coal from the rivers to continental ports and brought back sand. New designs in table and ornamental glassware are constantly being produced, and the best quality pressed glass is a serious rival to cut glass. Manufacturers are steadily modernizing their plants to procure greater output and better finished articles. Among the uses of pressed glass are table and cooking ware, bowls, vases, jugs, drinking glasses, lenses for lamps of all kinds, food containers, and pavement lights. Turnbull's Glassworks at Sunderland is owned and managed by Mrs. Race, granddaughter of the founder, with a staff of

Influence of sodium nitrate and arsenious oxide on

reactions occurring during the melting of glass. M. A. BEZBORODOV, N. D. ZAVYALOV, T. A. LADE, AND G. M. MINKIN. *Jour. Soc. Glass Tech.*, **22** [91] 218–34T (1938); see "Behavior—," *Ceram. Abs.*, **17** [4] 136 (1938). G.R.S.

Research on the relative hardness of glasses according to the grinding method. B. N. MOSKVIN. *Optiko-Mekh. Prom.*, **7** [9] 1–4 (1937); abstracted in *Chem. Zentr.*, **1938, II,** 2009.—The hardness of glasses can be determined by their loss in weight on being ground with a plane disk or cone of brass with the addition of an aqueous suspension of corundum powder (all at once or continuously). Several measurements are given, *e.g.*, the equation for flint glass $1/K = 155 \times C^{-1.435}$, as the relation between the percentage content (C) in Pb and the coefficient of hardness $1/K$ (K = coefficient of grinding off) ascertained after the grinding test. The coefficients of hardness given in a table for different glasses can be used in technical calculations. M.V.C.

Significance of the Schardin crack-spreading velocity in glass. A. SMEKAL. *Glastech. Ber.*, **16** [7] 228–31 (1938).—The velocity of crack propagation in glass as determined by Schardin ("High-frequency—," *Ceram. Abs.*, **18** [1] 17 (1939)) must remain lower than the sound velocity, as it represents not the propagation of a microscopic elastic disturbance in a quasi-homogeneous medium but the spreading of a submicroscopic process on a front through an essentially inhomogeneous medium. The Schardin method, therefore, should offer a means of characterizing submicroscopic flaws present in glass. It is predicted that the velocity, within certain limits, is independent of the temperature and velocity of loading of the glass at the beginning of the break. J.F.H.

Slag glass. Y. P. VARSHNEY. *Science & Culture*, **4** [1] 45–47 (1938).—Experiments on the use of slags produced in iron and steel plants as a constituent of glass batches are detailed. Orthoclase feldspar, which is abundantly available in this country, was used, partly replacing the more costly soda ash. The use of feldspar in large quantities necessarily involves the introduction of a higher percentage of alumina. Owing to difficulties in manufacture, aluminous glasses have not been largely used in making hollow glassware, but they are particularly suitable for making pressed ware. V. shows that glass cheaply made with slag and feldspar can be easily used for manufacturing bottles, jars, floor tile, roof tile, etc., in various transparent colors as well as in opaque and black varieties. Tried on a semicommercial scale, the batch became workable after about 16 hrs.' melting in a pot furnace at 1350°C. In these glasses larger percentages of potash give good brilliance, and, as potash and soda are in almost equal proportions, chemical durability is good. Cost is reduced about 50% by the use of slag batches. A.P.S.

Strength of quartz glass at elevated temperatures. W. DAWIHL AND W. RIX. *Z. tech. Physik*, **19** [10] 294–96 (1938).—Rods and tubes made from quartz glass were tested. The mechanical strength of quartz glass is 33⅓% higher at 1470°F than at room temperature. The shape of the surface of fractures in tests of tensile strength is explained by a theory developed by Smekal ("Mechanical—," *Ceram. Abs.*, **17** [5] 179 (1938)). W.M.C.

Tank practice. PERCY HALLER. *Glass*, **15** [10] 400 (1938).—H. discusses temperature control of glass tanks and the use of air-cooling to increase the life of the flux blocks. Side-wall construction, in which the wall is supported independently of the flux block, is described. B.C.R.

Thermal insulation of glass and plate glass. JOSEPH CARLIER. *Verre & Silicates Ind.*, **9** [12] 136–37 (1938).—In modern construction, the use of metal framework has permitted the building of thinner walls with large glass surfaces. A low coefficient of thermal transmission has been obtained for walls with appropriate insulators, but the coefficient for glass surfaces remains high. To lower the coefficient of thermic transmission of glass C. recommends covering one side of the glass with a plastic insulating mix, transparent or translucid and protected from the humidity of the air, of a solution of "phenol-formolic azolone." This resin does not harden when heated. It is soluble in aliphatic and aromatic alcohols; ketones; ethyl, butyl, and amyl acetates; palatinol; and tricresylphosphate; it is not soluble in oils or saturated or unsaturated hydrocarbons and is not thermoactive. Its coefficient of thermic transmission is established as follows: Cal./cm. × sec. × °C = 65×10^{-5}. The coefficient of thermal expansion is 90×10^{-6}, the dielectric constant is 7, and the density varies between 1.2 and 1.3. Under the action of air and air moisture this resin loses transparency and becomes opalescent; for this reason it must be placed between two or more sheets of glass whose edges are glued by an impermeable cement. If transparency is not required, the layer of resin can be applied to the inside surface of the glass, and luminescent, phosphorescent, or colored ingredients can be introduced for decoration or advertising effects. The inside of electric-light bulbs can be coated to reduce heat liberated or to obtain special effects. A thickness of 1.5 mm. of resin between two panes of glass lowers the coefficient of thermic transmission to 2.6. M.V.C.

Viscosity and electrical resistivity and their bearing on the nature of glass. N. W. TAYLOR. *Jour. Amer. Ceram. Soc.*, **22** [1] 1–8 (1939).

Viscosity measurements of the Na_2O-SiO_2 glasses. Criticism. G. HEIDTKAMP AND K. ENDELL. *Jour. Soc. Glass Tech.*, **22** [91] 235–36T (1938). **Reply to criticism.** E. PRESTON. *Ibid.*, pp. 237–42T. See *Ceram. Abs.*, **18** [1] 18 (1939). G.R.S.

BOOKS

Properties of Glass. GEORGE W. MOREY. American Chemical Monograph Series. Reinhold Publishing Corp., New York, 1938. 561 pp. Price $12.50. The past twenty-five years have produced more genuinely scientific work on glass and more technical papers concerning this material than all previous history. It is particularly appropriate that a man of sound training in mathematical physics and physical chemistry, who has devoted these years to working with glass and who has contributed outstanding researches and interpretations on the subject, should undertake the writing and compilation of this book. George W. Morey is conceded a high rank, if not indeed first place, among American glass technologists. He was assigned the task of writing this book by the Board of Editors of the American Chemical Society in 1924, at a time when his famous work on phase equilibrium relationships was only fairly under way. From these researches at the Geophysical Laboratory and from studies in many other laboratories scattered over the world, a wealth of data accumulated. M.'s problem was to find the suitable stopping place—to bring this book thoroughly up to date and to include all worth-while material without postponing too long its actual publication.

This book bears evidence that the fourteen years of its time of preparation have been well spent. The text is deliberate without being overlong. The subject is completely and concisely covered. M. has been more than an editor and compiler, because he has lived intimately with his material and has done much creative work. He has been able not only to bring the data together and present them in a well-arranged, eminently readable form but also to treat them critically and to write first-hand concerning much present-day knowledge. M. has stayed within the limits of the title. Technology, as it includes raw materials, fuels, furnaces, tools, and forming processes, is not dealt with except where the specific physical properties of glass might be best illustrated with reference to their applications.

In the chapter on history and definition, M. writes as only one could write who has read the best that is written in the old books on the history of this art and who has thought deeply and clearly on the nature of glass. Twenty-six characterizations of glass from a 17th-Century writer lead up to the best discourse in the book, during which M. arrives at his own excellent definition of glass.

A chapter on devitrification is developed from the

viewpoint of phase equilibria and includes the fundamental diagrams of Morey and Bowen which, for the first time, gave a true picture of soda-lime glasses. The chapter on composition carries a wealth of statistical data on commercial and experimental glasses and brings together results of studies on gases in glass in a way not hitherto attempted.

Chemical durability and the interesting problem of what happens when water attacks glass are discussed. Unless one reads carefully the discussion of equilibria between water and the potassium silicates, he might be misled into thinking that these are not capable of complete solution in water. Various methods that have been proposed since durability was first studied in the past century down to the modern methods now being selected for standard procedure are thoroughly treated.

The subject of viscosity is given as much space as the author's specialty, devitrification. A generous number of curves and tabulations is presented, and complete bibliographic data appear in the footnotes. Annealing is treated in the modern mathematical way, and the best of recent studies on the rate of strain release are included. Matters of lesser importance, such as surface tension, heat capacity, and thermal conductivity, are briefly covered. A surprising and perhaps disproportionate amount of space is given to density. This may have been found necessary because of the mass of data which has accumulated. Not only has this been an easy type of experimentation, but, as M. points out, it was one of the paths by which some investigators hoped to arrive at conclusions regarding the existence of compounds in glass. He does not deny these, but neither does he encourage the belief that their presence can be demonstrated, at least in the present knowledge of the liquid state. Similarly, coefficient of expansion requires a good deal of space, both because of its importance in commerical glasses and because of the wealth of data. In the discussion of elastic properties occurs an example of M.'s ability to evaluate his material. In writing of Winkelmann and Schott's factors for calculating Young's modulus, he remarks that the agreement they find within the experimental error between observed and calculated values is "not so much a justification of the additive hypothesis as an indication of the crudity of the measurements."

Early in the chapter on strength, M. states that with glass there appears to be no region of plasticity; he makes this point elsewhere in the book. Numerous researches are cited to indicate the variety of specimens and methods used in the search for acceptable values for the tensile strength of glass and to show how the search is complicated by the effects of surface condition, heat treatment, and rate of loading. Thermal endurance, as handled by a number of experimenters, has been accorded rather complete mathematical treatment, notwithstanding the preliminary remark that "breakage will be determined largely by the condition of the surface."

The chapter on hardness is well concluded with the sentence, "At present, what hardness is and how it can be measured are not known." The chapter on optical properties includes a wealth of statistical information about the glasses which are of such paramount importance to the scientific world and of such small commercial significance as a product. This is the longest chapter in the book. The work on electrical conductivity and dielectric properties consists substantially of what has already appeared in the book by Littleton and Morey (*Ceram. Abs.*, **12** [12] 419 (1933)). A few pages suffice for the slightly investigated magnetic properties.

Beginning by saying, "Little is known about the constitution of glass," M. gives some of his best thought and exposition to this subject and presents summaries of the interesting work that has been done on the behavior of glass in its annealing range, interpreted from the standpoint of constitution; he also treats fully the subjects of frozen-in equilibria and the random network demonstrated by X-ray studies. From the latter he makes out a case for his own definition of glass as essentially "an undercooled liquid."

The index has been made brief by grouping minor specific properties under general groups of properties. Authors and subjects appear in the same index, distinguished by the use of different type faces.

This splendid book adequately presents the knowledge of glass as of 1938. The complete competence of the author and the critical thoroughness with which the various subjects are treated assure the reader that it is sufficiently encyclopedic. It is true that Glastechnische Tabellen includes a greater mass of numerical and graphic data and that, in the present book, many researches have been mentioned only by name or not at all; but we feel confident that the selections have been expertly made and that nothing contributing to the truth has been neglected.

S. R. SCHOLES

Working Precision Optical Glass (Le Travail des Verres d'Optiques de Précision). C. Dévé. Published by Revue d'Optique, Paris. 372 pp. Price 48 F. Reviewed in *Verre & Silicates Ind.*, **8** [10] 191–92 (1937).—This revised edition includes several new chapters dealing mostly with the mathematical theory of surface working, grinding of crystals, metallization of mirrors, etc. The first part of the book is devoted to the properties and defects of optical glass and its manufacture and working. The chief value of this book lies in the lucidity with which the subject is treated and its methodical arrangement. An appendix gives a list of optical terms. See "Five—," *Ceram. Abs.*, **17** [4] 127 (1938). M.V.C.

PATENTS

Apparatus for bending glass sheets. P. P. MARSHALL (Pittsburgh Plate Glass Co.). U. S. 2,137,115, Nov. 15, 1938 (May 29, 1937).

Apparatus for cutting curved glass sheets. A. L. HARRINGTON (Pittsburgh Plate Glass Co.). U. S. 2,137,112, Nov. 15, 1938 (Feb. 15, 1938).

Apparatus for making sheet glass. A. D. NASH AND WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 2,137,116, Nov. 15, 1938 (Oct. 31, 1936).

Disk-shaped grinding tool for sheet glass. PILKINGTON BROS., LTD. Ger. 663,797, July 21, 1938 (Feb. 4, 1935); XII/67*a*. 15. A disk-shaped rotating tool for grinding sheet glass has its grinding surface divided, by two groups of ridges traversing each other (scattering and mixing ridges), into a number of small blocks. The scattering ridges run from the middle of the disk to the circumference in a direction which is diagonal to the circumference of the disk-shaped tool, and the surfaces of the small blocks which are formed by these ridges are arranged to form various angles with the radius of the disk (all less than 90°), so that the outer ends of the blocks do not lag behind the inner ends of the corresponding blocks. The mixing ridges traversing the scattering ridges have a slight tendency to run spiral to the circumference of the disk of the work tool, and the small blocks formed by these ridges have characteristic shapes due to these spiral-running ridges. D.A.B.

Drawing sheet glass. J. B. WATT (Pittsburgh Plate Glass Co.). U. S. 2,137,120, Nov. 15, 1938 (Dec. 12, 1936).

Equipment for producing glass threads. SOC. ANON. VETRERIA ITALIANA BALZARETTI MODIGLIANI. Fr. 830,856, Dec. 16, 1937; *Chem.-Ztg.*, **62** [82] 745 (1938). D.A.B.

Glass feeder. JOHN TIPPING (Ball Bros. Co.). U. S. 2,137,734, Nov. 22, 1938 (July 21, 1936).

Glass fibers or filaments and method of producing. SCHLESISCHE SPIEGELGLASMANUFACTUR C. TIELSCH GES. Brit. 494,452, Nov. 9, 1938 (Sept. 30, 1936).

Glass sheets, tile, etc. F. D. PARKINSON. Brit. 494,416, Nov. 9, 1938 (March 24, 1937).

Hand tool for use in the manufacture of hollow glass blocks. OWENS-ILLINOIS GLASS CO. Brit. 495,273, Nov. 23, 1938 (May 7, 1937).

Joining a quartz object with a metallic part or another quartz object by soldering or brazing. HANS PULFRICH (Patent-Treuhand-Ges. für elektrische Glühlampen m. b. H.). Ger. 663,897, July 28, 1938 (Feb. 20, 1937); VI/32*b*.

10. The quartz object is coated with a quartz-like layer having a lower fusing point than quartz and consisting of quartz with an admixture of Al_2O_3; to this layer a porous metallic coating is applied as foundation for a soldering metal which does not alloy with the foundation metal but which produces a union with the applied metal part or quartz object having also a quartz-like coated layer of lower fusing temperature and a porous metallic coating on top of it. D.A.B.

Laminated article. J. W. HAUGHT (E. I. du Pont de Nemours & Co.). U. S. 2,136,436, Nov. 15, 1938 (Feb. 13, 1936). Laminated glass comprises a sheet of glass and bonded thereto an interlayer sheet comprising 100 parts of cellulose nitrate and 60 to 150 parts of a plasticizer composition therefor composed of 83 to 17% of diamyl phthalate and 17 to 83% of octadecanediol-1,12 diacetate.

Laminated glass. WALTER BAUER AND PAUL WEISERT (Röhm & Haas Co.). U. S. 2,137,377, Nov. 22, 1938 (Feb. 20, 1934).

Leers for flat glass. PILKINGTON BROS., LTD., AND F. E. SLOCOMBE. Brit. 494,910, Nov. 16, 1938 (May 19, 1937).

Lens. R. N. FALGE (General Motors Corp.). U. S. 2,137,079, Nov. 15, 1938 (Nov. 22, 1935).

Lens for asymmetric head lamps. J. L. KOUBEK (General Motors Corp.). U. S. 2,137,055, Nov. 15, 1938 (June 3, 1936).

Making frosted bulbs. J. J. FLAHERTY (Wabash Appliance Corp.). U. S. 2,137,683, Nov. 22, 1938 (July 28, 1937). The method of producing an inside frosted glass bulb consists in subjecting the interior surface of a glass bulb to an etching solution including, in approximately the following proportions by weight, water 9.3, ammonium bifluoride 23.4, a 60% solution of hydrofluoric acid 46.8, ammonium bicarbonate 14.6, and soda ash 5.9% for less than 2 min. at a temperature of about 47°C.

Making sheet glass. WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 2,137,117, Nov. 15, 1938 (Oct. 31, 1936).

Method of and apparatus for producing mineral wool. C. B. WHITE. U. S. 2,136,988, Nov. 15, 1938 (Dec. 12, 1936).

Mold-adjusting means for glass shaping machines. E. P. DORMAN (Ball Bros. Co.). U. S. 2,137,714, Nov. 22, 1938 (Jan. 30, 1935).

Mold for manufacture of articles of glass in combination with plastic materials. L. J.-B. FORBES (Pilkington Bros., Ltd.). U. S. 2,137,472, Nov. 22, 1938 (Feb. 5, 1936; Sept. 29, 1937).

Partially rendering a ground or matlike surface on the inner surfaces of glass bulbs for electric lamps or glass flasks. TOMISABURO NARUSE. Ger. 663,883, July 28, 1938 (Sept. 9, 1930); 32*b*. 6. The opening of the glass receptacle is constructed upward, and the etching liquid, which has been thickened with insoluble or swelling pulverized material, is introduced into the opening by means of a pipe and left there until the part to be etched has reached the desired stage; after completion of the etching process, the liquid is removed by the same pipe. D.A.B.

Polishing level surfaces such as mirror glass. "LUMIÈRE & CLARTÉ," SOC. ANON. HOLDING. Ger. 664,250, Aug. 4, 1938 (Nov. 20, 1934); XII/67*a*. 15. Before the polishing process, the work piece is heated from above or below or from above and below to a temperature of at least 80° to 100°C; polishing tools are used whose effective surfaces are made of impervious, nonabsorptive materials and which deliver the polishing agent in an almost dry state. D.A.B.

Process and device for tempering glass. ALBERTO QUENTIN. U. S. 2,137,061, Nov. 15, 1938 (Feb. 23, 1937).

Producing blown hollow-glass objects. WERNER DUDEK. Ger. 664,056, Aug. 4, 1938 (Feb. 18, 1937); VI/32*a*. 15. Blown hollow-glass objects with attached glass parts are produced from a corresponding glass mixture and get their final shape from a form or die. The mass of glass connecting with the glass part and securely held by its end is worked without application of form or die by simultaneous pulling and blowing into an extended hollow object and is finally blown into the finished shape of the hollow glass by means of a form or die. The pear-shaped mass of glass designed for the part of the glass which is to be blown and attached to the pressed glass part is provided with only a slight curvature at the secured end; the glass mass is extended without application of a form and, at the same time, given its shape by a current of compressed air; it is finally blown into the finished shape by means of a form. During the shaping of the hollow-glass part, the attached glass part is held firmly in its form, which does not turn. D.A.B.

Producing etched designs on glass by photogravure. KODAK A.-G. Ger. 660,662, May 5, 1938 (March 23, 1935); IV*a*/57*b*. 5.01. A layer containing substances sensitive to light is applied to the glass surface. This light-sensitive substance consists of stereo-isomeric materials which possess several ethylene members whose carbon atoms need not be joined to carbonyl groups and resins, gum, or isonitrosoacetophenone as a colloidal carrier for the light-sensitive material. A natural or artificial wax, in amounts of 1 to 2%, is added to increase the adhesiveness of the layer to the glass. D.A.B.

Producing hollow glassware. HARTFORD-EMPIRE CO. Ger. 664,456, Aug. 11, 1938 (May 22, 1936); VI/32*a*. 13. Hollow glassware is produced in but one form which constitutes the preliminary and final form. The preliminary blowing for shaping of the hollow glass ball is brought about by simultaneous raising up of a suction head in addition to contact with the form walls; this suction head holds the ball and the ball thus formed is blown up until it assumes the final shape of the hollow glassware by contact with the form walls. D.A.B.

Sealing electrical conductors into vitreous envelopes. H. P. BARASCH. U. S. 2,138,224, Nov. 29, 1938 (Jan. 11, 1938).

Structural Clay Products

Control in a brickyard. K. SPINGLER. *Ziegelwelt*, **69** [12] 146–47 (1938).—The necessity of control in a brickyard and the different methods of effecting it are studied. F.L.

Freezing and thawing of brick. J. W. MCBURNEY. Abstracted in *Jour. Wash. Acad. Sci.*, **28**, 411 (1938).—Freezing and thawing tests are useful in evaluating resistance to weathering. Twelve samples of 20 brick each were selected from each of 5 large samples representing 5 types of brick so that the distribution of physical properties of each small sample closely resembled each other. These comparable small samples were frozen and thawed up to 75 cycles using 7 different techniques. Three types of exposure to weather were also used. It was concluded that the greater the degree of saturation, the greater is the disintegration. J.B.A.

Frost tests on brick and tile and their limitations. B. BUTTERWORTH. Presented at Internat. Assn. for Testing Materials, London Congr., May, 1937; abstracted in *Brit. Clayworker*, **46** [542] 87 (1937). R.A.H.

Making a hollow brick closed on five or all sides. G. HELM. *Ziegelwelt*, **69** [19] 232–35 (1938).—All patents which deal with this problem are reviewed. 20 figures. F.L.

Sulfur content of sand. W. MARSCHNER. *Tonind.-Ztg.*, **62** [7] 76–77 (1938).—After a discussion of the influence of sand and quartz on the drying and firing behavior of brick, M. lists the results of the determination of total and soluble sulfur in sands used for brickmaking in widely scattered localities. The figures vary from 0.009 to 0.017% for soluble sulfur and from 1.0 to 1.2% for total sulfur. W.K.

BOOKS AND SEPARATE PUBLICATIONS

Clay Building Materials (Brick and Roofing Tile). *Dept. Sci. Ind. Research, Bldg. Research Board Rept.*, 1937. H. M. Stationery Office, London. The work of the Building Research Board is surveyed. Results of experiments on clay products are as follows: (1) An attempt to devise a refiring test for detecting the original firing temperature of brick of unknown origin was unsuccessful. (2) By firing brick above 1000°C soluble salts are eliminated. (3) The ratio of porosity to the saturation coefficient (ratio of rapid absorption to total absorption) shows that increasing the firing temperature increases frost resistance, but neither durability nor resistance to frost is dependent solely on the total porosity and saturation coefficient. (4) Dampness in tiled roofs is caused by (*a*) highly cambered tile, (*b*) the capillary transfer of water to the battens, (*c*) frost, and (*d*) corrosion of the nibs by soluble salts due to underfiring of the tile. The report includes information on nonceramic building materials. A.B.SEARLE

Freezing Certain Building Materials. W. N. THOMAS. *Dept. Sci. Ind. Research, Bldg. Research Tech. Paper*, No. 17. Price 2s 6d. T. deals chiefly with the effect of frost on building stones, but blue brick, sand-lime brick, and clay tile are included. Blue brick lose 33% of crushing stress/strain on freezing, but sand-lime brick lose only 22% and a roofing tile only 7%. It was found that the change in the stress/strain ratio produced by freezing was a better indication than the simple reduction in crushing strength. A.B.SEARLE

Principles of Modern Building: Vol. I, Walls, Partitions, and Chimneys. R. FITZMAURICE. H. M. Stationery Office, London, 1938. Price 10s 6d net. Reviewed in *Brit. Clayworker*, **47** [559] 243 (1938).—The series inaugurated with this volume has been undertaken by the Department of Scientific and Industrial Research at the request of the Royal Inst. of British Architects and the Chartered Surveyors' Inst. and represents the results of 17 years' work in the Building Research Station. The intention has been to deal with broad principles rather than with practical instruction, *i.e.*, with the functions of a building and with the structural elements of which it is composed, such as the causes and prevention of dampness, the avoidance of smoky chimneys, the insulation of a room from noise, and the retention of warmth. Brickwork, in all its aspects and qualities, is treated fully, especially from such standpoints as compressive strength, thermal expansion, immunity from damp and frost action, efflorescence, etc. The book is liberally illustrated with photographs, drawings, and graphs and contains a full list of references and appendices dealing with the Model By-Laws of the Ministry of Health and with British Standard Specifications applicable to walling. R.A.H.

PATENT

Hollow brick or blocks for floors and ceilings. F. SCHAFER. Brit. 495,398, Nov. 23, 1938 (May 13, 1936).

Refractories

Aluminum industry of Japan. ROBERT J. ANDERSON. *Mining Mag.*, **59**, 73–85 (1938).—Aluminum production in Japan is rapidly increasing. Bauxite has not been found in Japan. Alunite and high-alumina clays have been found in Japan and Korea, and these have been used as ore. High-grade bauxite was first obtained from the Dutch East Indies. Some deposits of good quality have recently been found on the islands of Palau, Yap, and Ponape. Another source is the state of Johore, South Malay Peninsula. Use of other ores than bauxite will be discontinued. Complete statistics on aluminum products are given. W.D.F.

Apparatus for determining thermal conductivity of heat-insulating materials at high temperature. CHIZHNYAKOV. *Zilein-Tech. So.*, Series 27, No. 1881, 6 pp. (1937); abstracted in *Referat. Silikatliteratur*, **5** [5] 5232 (1938).—C. describes a new arrangement permitting the determination of thermal conductivity of insulating brick; brick of standard size may be tested with this apparatus. M.V.C.

Appearance of slag tests of a basic open-hearth process. S. LEVIN. *Teoriya & Prakt. Met.*, **9** [10] 18–19 (1937).—With less than 30% CaO the slag surface is uneven, dull, and dark gray; with 30 to 35% CaO the surface becomes more even, dark, and glossy; and with 35 to 40% CaO the surface is smooth, dark, and very glossy. When CaO is over 40% the surface begins to crack. With 25–27 to 20–22% SiO_2 there is some bulging of the surface which becomes more pronounced at 14 to 16% SiO_2. When FeO is 18 to 22% the inner mass is porous and is surrounded by a 2 to 3 mm. dense crust. At 15 to 16% FeO the crust increases to 6 to 8 mm. and the porosity of the mass decreases, but the blowholes still remain. The same is true when FeO is reduced to 10 to 13%. With 6 to 10% FeO the fracture is dense and almost free of blowholes. A MnO_2 content of about 20% causes rippling which disappears when the MnO_2 is less than 15%. B.Z.K.

Dolomite lining of the sintering zone of cement kilns. P. P. BUDNIKOV, K. F. MUKHIN, AND D. O. NIRENSHTEÏN. *Ukrain. Khem. Zhur.*, **13**, 115–31 (1938).—Only natural dolomites containing 6 to 9% silica and not less than 2% sesquioxides can be used as raw material; these alone are sufficiently refractory and stable in respect to hydration by moisture from atmospheric air and crumbling when cooled under 700°C. Stable dolomite can be prepared artificially by mixing dolomite waste with an appropriate proportion of admixtures ($SiO_2 + Al_2O_3 + Fe_2O_3$). The firing temperature of dolomites must not be under 1560°C, this being the lowest temperature insuring a minimum porosity of the dolomite. P.B. & E.S.

Dry pressing for maximum density. C. M. DODD. *Bull. Amer. Ceram. Soc.*, **17** [12] 465–77 (1938).

Factors influencing the durability of chrome-magnesite brick in basic open-hearth steelmaking furnaces. W. HUGILL AND A. T. GREEN. *Trans. Ceram. Soc.*, **37** [7] 279–95 (1938).—Reviewing the evidence obtained, the authors reach the following conclusions relative to the mechanism of the disintegration of chrome-magnesite brick in an open-hearth steel furnace: (1) Iron oxide is absorbed by the hot face of chrome-magnesite brick. In this zone the grains of chromite grow by taking up magnetite into solid solution. The matrix, which is relatively rich in magnesia, is largely converted into the less refractory magnesioferrite and metasilicates. (2) The strains set up by the growth of the chromite grains induce (*a*) a crumbling disintegration of the working face; (*b*) a movement of the mobile matrix within the brick until it reaches a zone where the temperature is such that it can solidify (capillary forces also assist in promoting action *b*); (*c*) a layer $\frac{1}{2}$ to 1 in. thick to be formed by this process. (3) When the hot face has been further worn back by disintegration, the temperature increases at the second zone and liquefaction again takes place, with the result that a more serious breakdown of the surface occurs. R.A.H.

Heat propagation controls furnace economy. J. G. COUTANT. *Iron Age*, **141** [11] 27–29 (1938).—Open-hearth furnaces in America are usually insulated, while those in Europe are not. There are wide differences of opinion regarding the efficacy of insulation, the European viewpoint being based on sound mathematical reasoning. In important French investigations, reported in 1937, attention was given to (1) empirical and comparative methods and (2) methods tending to give absolute values. Each group may be subdivided into methods based on (*a*) measuring the speed of propagation, (*b*) observation of thermal gradient and heat diffusivity, and (*c*) calorimetry. Results of French research are

indicated and compared with those of German work which C. considers less accurate. E.H.McC.

Increase of durability of hearth brick for basic open-hearth furnaces. S. LOTCHILOV. *Stal*, **1937**, No. 1, p. 33.—To increase the durability of hearth brick for open-hearth furnaces L. recommends welding the hearth brick by mixing magnesite powder with the slag powder of open-hearth furnaces; this method is better than welding by dolomite. The process is described. B.E.K.

Life of refractories in open-hearth furnaces. A. RUBAN. *Teoriya & Prakt. Met.*, **9** [10] 32–40 (1937).—R. studied refractories destruction in open-hearth furnaces during heating up. At one plant the composition was SiO_2 94.6, Al_2O_3 1.12, Fe_2O_3 0.80, and CaO 2.37%. Of the brickwork, 65% had rounded edges, 75% had broken edges, 80% were checked or cracked, 50% were misshapen, 15% were warped, 15% had Fe spots, and 40% did not ring. At another plant the composition was SiO_2 95.35, Al_2O_3 1.80, Fe_2O_3 0.90, and CaO 2.19%. In this case 37% had rounded edges, 72% had broken edges, 90% were cracked or checked, 30% were misshapen, 30% were warped, 45% had Fe spots, and 42% did not ring. B.Z.K.

Plastic refractory for ladle linings. IRONTON FIRE BRICK CO. *Steel*, **101** [11] 40 (1937).—Ironton Nojoint, a plastic refractory, enables the foundry operator to get monolithic ladle linings which are much more resistant to the corrosive action of soda slags than ordinary ladle brick and which do not cut out. The material is made from a special type of fireclay grog. H.E.S.

Practical advantages in the use of special refractories. H. E. WHITE. *Ind. Heating*, **5** [10] 945–52; [11] 1061–63 (1938).—Special refractories are those consisting essentially of the crystalline materials fused alumina, mullite, and silicon carbide; the first and last are made in the electric furnace, while mullite is usually converted from kyanite, sillimanite, and andalusite by heating at high temperatures for long periods. The melting points of some materials are as follows: magnesia 2800°C, silicon carbide 2300° (dissociates), alumina 2050°, chrome oxide 1990°, mullite 1810°, and silica 1713°; the specific gravity of fire clay (fired flint clay) is 2.55 to 2.75; of crystalline alumina, 3.91 to 4.01; of mullite, 3.03 to 3.10; and of silicon carbide, 3.17 to 3.22. High-grade refractories should contain at least 85% of either of the last three minerals. Products are discussed, and causes of failure by erosion and slag action are described. Fused-alumina refractories are preferably used where high temperatures and high bearing loads are combined (piers and supports). Mullite brick have a high resistance to spalling and volume stability and are used extensively in the glass industry, owing to their low solubility in molten glass, and in metallurgical furnaces for their high strength and slag resistance. Bonded silicon carbide brick have proved extremely suitable for muffle furnaces for hardening high-speed tools, mainly because of their high heat conductivity which gives a more uniform temperature. They do not spall and are therefore used for hearth tile and linings, giving longer life and greater economy. A curve shows the most economical time to renew the lining. M.H.

Radiation properties of several silico-alumina refractories: II. A. BARITEL. *Chaleur & Ind.*, No. 216, pp. 299–311 (1938).—B. discusses the accuracy of radiation measurements. The surface cavities are expressed by the relation $C = \sqrt[3]{(\text{total porosity})^2}$. These increase the radiating surface and tend to give too high a value for monochromatic radiation, especially in the shorter wave lengths. This effect is negligible in the infra-red radiations, and the value for total emission is scarcely affected by fine pore cavities. Five high-fired mixes of alumina and silica were tested. Total emission at temperatures from 1200° to 1500°K and energy distribution in the radiations in the neighborhood of 1200°K were measured and plotted in 20 graphs. In practice the effect of gases, especially CO_2, by convection modifies the radiation characteristics of refractories. A bibliography is given. For Part I see *Ceram. Abs.*, **17** [6] 222 (1938). V.D.F.

Raw materials supply for the German refractories industry. F. HARDERS. *Stahl & Eisen*, **57**, 1127 (1937).—Clays are chiefly won inside the Reich. The best quartzite is nearing exhaustion, but there is plenty of the easily convertible "felsquartzite." Magnesite is scarce, but methods are available of extracting it from dolomite and carnallite. All chrome ore is imported. Bavaria supplies part of the graphite; the remainder comes from abroad. Special refractories, including silicon carbide, corundum, and sillimanite, can be made from home materials. There are great reserves of dolomite, mortar sands, and silica for rammed linings. L.R.B.

Recent investigations on slags. F. F. FRANKLIN. *Blast Furnace & Steel Plant*, **26** [4] 366–69; [5] 493–95 (1938).—Viscosities of slags are dependent upon the chemical composition. The values for viscosity of slags are not accurate owing to inaccuracies in the methods of determining the viscosities. In general, the extent of attack by slags upon refractories depends upon their chemical composition and the type of refractory used. The density, fluidity, and surface tension of slags are important in the wetting or penetrating of surfaces by the slag before reacting. Stewart found the order of increasing resistance to slag erosion by refractories to be about as follows: silica, chromite, magnesia, high heat duty flint fire clay, super fire clay, intermediate mullite, high alumina (diaspore type), high alumina (electrically fused), high mullite (bonded), cast mullite, and silicon carbide. Singewald, in his petrographic investigations, recognizes three types of slags: (*A*) all SiO_2 combined with all CaO and MgO and with a part or all of the FeO and MnO; added CaO displaces the Fe and Mn until pure CaMg orthosilicate is formed; (*B*) passes from CaMg orthosilicate into pure dicalcium silicate with liberation and precipitation of MgO as periclase which absorbs some FeO and MnO; (*C*) upon further addition of CaO, dicalcium ferrite is formed until at last an excess is found as crystals of free CaO in the slag. Methods of chemical analysis of slags are briefly summarized. References to work on slag inclusions are made, and slags as by-products, for use in construction and agriculture, are discussed. E.J.V.

Recording of heat and temperature conductivity as function of temperature by means of simple stable temperature fields dependent on time. E. GRÜNWALD. *Elektrowärme*, **8** [8] 219–22 (1938).—G. develops the theory of a method which permits, especially for refractories, the making of a continuous record of the temperature and the heat conductivity coefficient as a function of the temperature; temperature conductivity is (heat conductivity)/(specific heat × specific weight). M.H.

Refractories developed for high temperatures. ANON. *Steel*, **101** [16] 67 (1937).—Monofrax block is a new high temperature refractory developed at Mellon Inst. for the Carborundum Co. The blocks are cast from a melt produced in the electric furnace. They are at present being used in glass furnaces and furnaces for handling molten slag. H.E.S.

Refractory firestones of Ohio. E. A. BURR. *Blast Furnace & Steel Plant*, **26** [5] 490–92, 520–21 (1938).—Firestone is a natural silica rock which usually lies at a considerable depth, supporting a great pressure from the overburden. This great pressure, supplemented by the cementing action of interstitial matter composed largely of amorphous silica, forms the unusually strong bond by which the grains of silica composing the rock structure are held together. Finely divided iron carbonate, alumina, and other compounds in small quantities are distributed through the mass and act as a further bonding agent. The structure is rather open and porous, permitting expansion and contraction with a minimum of spalling action at high temperatures. Typical minerals present in Ohio silica rock in small quantities are listed. Five structures recognized in the rock are described. Crushing strength is 8000 to 10,000 lb./in.^{2}. Transverse strength tests show a modulus of rupture of 1200 to 1400 lb./in.^{2}; apparent specific gravity is about 2.14. Methods of quarrying are described. Expansion, which is partly reversible,

takes place to the extent of 2% linear up to 2600°F, occurring mostly below 1063°F. Porosity is 18 to 20%, which gives good resiliency, and Ohio rock will withstand considerable pressure under load at high temperatures without spalling, at the same time compressing the joints so as to make them virtually immune from gas attack. Wherever an acid lining can be used and where abrasion and temperature conditions are extreme, natural silica rock is suitable, being economical in respect to fuel saving, length of service, ease of installation on account of the larger blocks used, and low cost at which it can be produced in large quantities. See "Silica firestone—," *Ceram. Abs.*, **17** [1] 22 (1938). E.J.V.

Refractory materials for flame furnaces for copper production. P. S. MAMYKIN. *Tsvetnye Metally*, **12** [10] 42–53 (1937); abstracted in *Chem. Zentr.*, **1938, II,** 746.—The suitability of various refractories, such as grog, silica, magnesite, chromite, chrome-magnesite, and forsterite, in the production of copper is dealt with. Light chrome-magnesite or magnesite brick were found to be suitable for crowns of these furnaces. M.V.C.

Silica brick with increased thermal resistance. I. L. MOVSCHEVICH. *Vestnik Inshenerov Tekh.*, **1937,** Sept., p. 560; abstracted in *Chem. Zentr.*, **1938, I,** 2608.—Dinas brick of higher thermal stability are obtained when their content of fine granules (0.5 mm.) does not exceed 37% (average), with a maximum grain size of 7 mm. and an alkali content of about 1.5%. Porosity of these brick is lower (up to 14.5%) and their resistance to slag attack is higher. Such brick withstood several metallic melts at 1400° without forming fissures. A vibrating molding machine was used in their production. M.V.C.

Silicon carbide. Extended uses as a refractory. ANON. *Chem. Age* [London], **39** [1006] 277 (1938).—Silicon carbide is now being more widely used in cements, crucibles, retorts, combustion chambers, etc., as such refractory materials are of great advantage where rapid heat liberation is desired and where there must also be freedom from soot or smoke in contact with the material which is being heated. In boilers with a high rate of fuel combustion (35,000 to 50,000 B.t.u./cu. ft./hr.) the fireclay brickwork forming the heating chamber burns out quickly since the fused coal ash readily reacts with the brick at the higher temperatures and so destroys the furnace setting; silicon carbide brick cooled with air or water, however, have been found to be more durable. The high heat conductivity of the silicon carbide allows heat to be withdrawn from the inner surface to the cooling medium at a rate sufficiently rapid to chill the exposed face of the brickwork. Silicon carbide has also been used extensively for intermittent types of oil burners in the form of ignition baffles against which the oil is sprayed. Its highly refractory nature and ability to conduct electricity has also led to its use as a material for making electrically operated heating elements, temperatures as high as 1500°C being attained. A.B.S.

Standard method for determining the porosity of refractory materials. ANON. *Jour. Soc. Glass Tech.*, **22** [90] 102–103P (1938).—The British Refractories Research Assn. standard method of porosity determination is given. Tests are outlined, and formulas for calculating percentage apparent porosity, apparent specific gravity, and percentage true porosity are included. G.R.S.

Synthetic super refractories. V. CHARRIN. *Céram., Verrerie, Email.*, **6** [6] 189 (1938).—Super refractories which play an important part in ceramics and metallurgical industries are as follows: (1) Alundum, an artificial emery. (2) Carborundum, which crystallizes between 1800° and 2200° and varies widely in composition, one type containing 69.10 silicon, 30.20 carbon, 0.15 calcium, and 0.55 iron and aluminum. It is used as abrasive for electric resistances and as a refractory. It resists slag acids and sustains reducing atmosphere well. A coating of a liquid mixture of Carborundum and potassium silicate of a half-millimeter thickness is often used for protecting refractory brick. (3) Siloxicon, a kind of silicon oxycarbide of varying composition. It is very plastic and is used in furnace masonry, converter linings, blast pipes, crucibles, and muffles. (4) Boron carbide, the hardest synthetic substance, used for working some diamonds but not extensively used in ceramics. It is made in an electric furnace from a mixture of petroleum coke and boric acid. It resists all dilute or concentrated solutions of acids or alkalis besides oxidizing acids and consequently has many uses. (5) Tungsten carbide, prepared from a mixture of tungstic acid, iron, and petroleum coke. It is hard and refractory and is used in many alloys; it has a fusing point of 3140°. (6) Titanium carbide, which has a fusing point of 3410°. (7) Zirconium carbide, which fuses at 3800°. (8) Tantalum carbide, fusing at 4150°. (9) Tantalum and hafnium carbide, which fuse at 4215°. M.V.C.

BOOK

Refractory Concrete. LAFARGE ALUMINOUS CEMENT CO. Reviewed in *Concrete & Constructional Eng.*, **32** [6] 378 (1937).—Aluminous cement has high refractory properties, and the greater the refractoriness of the aggregate the more refractory the concrete will be. The aggregate should be crushed fire brick, brick grog, or higher refractory material such as sillimanite, chrome, and chrome magnesia. Recommended proportions are 3 cu. ft. of coarse aggregate (3/4 in. to 1/8 in.) and 2 cu. ft. of fine aggregate (1/8 in. down) to 1 cu. ft. (90 lb.) of aluminous cement. The crushing strength of the refractory concrete when hot ranges from 1120 to 2310 lb./sq. in. at a temperature of 1200°C with a cement content ranging from 13 to 32% by weight. F.G.H.

PATENTS

High temperature furnace insulation. A. S. NICHOLS (Illinois Clay Products Co.). U. S. 2,139,172, Dec. 6, 1938 (May 12, 1934). The method of improving the durability of the silica brick roof of a high temperature open-hearth furnace is characterized by operating the furnace at an internal temperature of about 3000°F, heating the outer face of the silica brick in the roof to about 2000°F by reducing radiation from the top of the roof by a layer of lightweight exfoliated vermiculite for a prolonged period to effect a substantial conversion of the outer portion of the silica brick into more stable forms of silica, such as tridymite, having lower coefficients of expansion.

Lining kilns and lining produced thereby. G. E. SEIL (E. J. Lavino & Co.). U. S. 2,137,184, Nov. 15, 1938 (Feb. 28, 1938).

Producing fireproof brick of high refractoriness from chromium ore and magnesium oxide. MAGNESITAL G.M.B.H. Ger. 664,044, July 28, 1938 (Sept. 27, 1929); VI/80*b*. 8.04. Brick of high refractoriness is produced from mixtures of chromium ore and dolomite or sintered magnesium oxide of any source. Magnesia or dolomite in the sintered or fused state and chromium ore with a content of at least 30% by weight of chromium oxide are used; such a proportion of these materials is chosen that the magnesium oxide content in the finished product will be from 10 to 80%. An intimate mixture of finely ground chromium ore and magnesium oxide or dolomite is added for leaning the coarser chromium ore and/or magnesium oxide or dolomite. The mixture is pressed and fired in the usual manner. D.A.B.

Refining materials containing alkaline-earth metals. I. G. FARBENINDUSTRIE A.-G. Ger. 664,474, Aug. 11, 1938 (Sept. 16, 1936); IV*b*/12*m*. 2. A method is given for refining mixtures of alkaline-earth metal compounds and magnesium, aluminum, or chromium compounds, especially for the extraction of magnesium compounds low in calcium and calcium compounds low in magnesium, from calcium and magnesium raw materials such as dolomite. The raw material in the oxidized form, *e.g.*, sintered dolomite, is suspended in water and, at an increased temperature, is treated with hydrogen sulfide, and the resulting solution of the alkaline-earth metal compounds separates from the solid residue. D.A.B.

Terra Cotta

Mechanical engobing. K. SPINGLER. *Tonind.-Ztg.*, **61** [83] 923–24; [84] 939–41 (1937).—S. discusses the principles of older and newer types of machines for the engobing of roofing tile. The dipping process used on the first machines is wasteful. Newer types are made for pouring or spraying with compressed air or by gravity pressure. The tile may have a horizontal position or a fixed or changing inclination. The best solution is a drum on which the tile change their position continuously so that one spray gun can spray the entire surface. This method also effects even distribution and drying. W.K.

Specifications and test methods for the quality of ceramic roofing tile in Switzerland. M. ROŠ. *Tonind.-Ztg.*, **61** [90] 1002–1003 (1937).—R. gives the new standards for roofing tile. Specifications for tests for capillary suction, permeability, transverse strength, and resistance to freezing are included. W.K.

Wall tiling on breeze block partitions. ANON. *Concrete & Constructional Eng.*, **32** [9] 548 (1937).—Breeze concrete partitions are not an ideal backing for glazed tiling. The principal causes of failure are movements of the breeze concrete combined with weak adhesion of the tiling. The most important factors to be considered are (1) the possibility of unsoundness of the aggregate due to the presence of unburned or partly burned coal, leading to expansion with consequent loosening of the tile if the adhesion is weak, and (2) excessive shrinkage of breeze and clinker concretes. F.G.H.

PATENT

Roofing tile. C. LUDOWICI KOMMANDITGES. AUF. AKTIEN. Brit. 494,392, Nov. 9, 1938 (Feb. 1, 1938).

Whiteware

China bedding. Substitution of alumina for flint. ANON. *Pottery & Glass Record*, **20** [10] 265 (1938).—The report of the Chief Inspector of Factories on the pottery industry states that a complete change from flint to alumina in placing (bedding) chinaware has now been made by all the fine china firms and many others. It is hoped that in 18 months flint will no longer be used for this purpose. Improvements in the quality of the ware as well as in the health of the workers are noted. See "Media—," *Ceram. Abs.*, **16** [2] 67 (1937). A.B.S.

Fireclay porcelain sanitary ware. ALBERT C. GERBER. *Bull. Amer. Ceram. Soc.*, **17** [12] 493–94 (1938).

Permanence of volume in a glycerine-lead cement. GINO GALLO. *Ann. Chim. Applicata*, **25**, 122–23 (1935).—In a series of experiments upon glycerine-lead pastes, G. ascertained that the hold of the carbon anhydride in the cement would increase as time went on. Its hold, tested by the work of about three years, would correspond to a 42% transformation in the weight of the paste mixture into basic lead carbonate. The volume of the litharge (vitreous lead oxide) stood in a 1 to 5.5 relation to that of the basic lead carbonate, causing the breakage of the insulators, especially as the portions of the cement exposed to the air were protected only by an impermeable varnish. K.R.

Pottery developments. ANON. *Times Trade & Eng.*, **44** [897] 54 (1938).—Josiah Wedgwood and Sons are building a pottery at Barlaston, near Stoke-on-Trent; it will be the first all-electric pottery in the British Isles and will employ 1400 people of whom 600 will be making fine earthenware. Rapid progress is being made in firing pottery, especially with the use of town gas as fuel. A.B.S.

Pottery and porcelain of the past. BERNARD RACKHAM. *Pottery & Glass Record*, **20** [10] 269–72 (1938).—R. outlines the history of pottery and porcelain from 4000 B.C. to about A.D. 1850. American pottery is not mentioned. A.B.S.

BOOK

Occurrence of sillimanite in Travancore, its importance and uses. S. DOGAR SINGH. Government Ceramic Concerns, Kundara, Travancore, 1938. 6 pp. Sillimanite occurs in grain form in beach sands with ilmenite, garnet, monazite, and zircon and can be easily separated by mechanical means. It is also a by-product of the china clay washing process. S. believes the mineral to be abundant. Sillimanite is superior in the manufacture of high-quality refractory porcelain and insulators for high voltages because it has good thermal endurance, low coefficient of expansion, and high load-bearing strength. S. developed the following theory in support of this: When quartzitic porcelain is subjected to sudden and repeated temperature changes, the amorphous matrix caused by the fusion of silicate does not allow the quartz crystals to expand or contract uniformly in all directions, hence the crystal tries to accommodate itself by developing a crack along the cleavage plane. This is one of the fundamental causes of breakage of the laboratory porcelain ware. Sillimanite crystals resist the attack of feldspar much better than the quartz crystals in the early stages of firing. As the temperature rises, the former are more or less completely dissolved. Unlike quartz crystals no allotropic modifications appear and there is no partial crystallization as sillimanite becomes monotropic after firing. Thus sillimanite crystals, when mixed with essential ingredients of porcelain, produce an ideal body which is chemically and physically in equilibrium and has a homogeneous nonporous structure which bears thermal and electrical shocks well. Sillimanitic porcelain is not very translucent due to the fact that sillimanite crystals are not porous and cell like as are those of china clay. The finely ground sillimanite particles act exactly like clay particles as far as their behavior toward the electrolytes is concerned. Uniform and thinner ware can therefore be produced without difficulty. A.P.S.

PATENTS

Improved dielectric material and method for making. KITSUZO FUWA AND SHUYO ITO (General Electric Co.). U. S. 2,137,135, Nov. 15, 1938 (Aug. 14, 1936). A dielectric material comprises a heat-treated mixture, the principal part of which consists of titanium oxide, which has also small but substantial proportions of aluminum oxide, magnesium oxide, and silicic acid homogeneously admixed with the titanium oxide.

Insulators, heat-resisting articles, etc., and methods of manufacturing. GASTON DELPECH AND ROGER LAMBERT (Soc. Anon. des Manufactures des Glaces & Produits Chimiques de St. Gobain, Chauny & Cirey). U. S. 2,136,877, Nov. 15, 1938 (April 6, 1934). A method of manufacturing heat-resisting and electrically insulating articles comprises mixing magnesia mica with a mixture containing silica, cryolite, boracic acid, and lead oxide, heating the resultant mixture to the softening temperature of the first-mentioned mixture, and compressing it.

Lead-free ceramic glazes. SOC. ANON. DES ANCIENS ÉTABLISSEMENTS PAILLETTE. Fr. 830,994, March 30, 1937; *Chem.-Ztg.*, **62** [82] 745 (1938). D.A.B.

Pottery ware and its manufacture. JOHNSON BROS. (HANLEY), LTD., AND E. J. JOHNSON, JR. Brit. 494,877, Nov. 16, 1938 (March 1, 1938).

Spark plug. M. J. FINNEGAN AND HOWARD BAER (Eclipse Aviation Corp.). U. S. 2,136,497, Nov. 15, 1938 (Jan. 6, 1936).

Spark plug. G. R. SMITH (C. V. S. Mfg. Co.). U. S. 2,138,558, Nov. 29, 1938 (Dec. 12, 1936).

Spark plug, insulating material for, and method of making. O. C. ROHDE (Champion Spark Plug Co.). U. S. 2,136,467, Nov. 15, 1938 (April 22, 1937).

Equipment and Apparatus

Air heater for a drier. K. SPINGLER. *Ziegelwelt*, **69** [22] 265–67 (1938).—S. shows in tables and diagrams the way to calculate the suitable temperature and air quantities in a drier. F.L.

Apparatus for photoelasticity-stress type quarter-wave plate of a large field. ZIRO TUZI AND MASATAKA NISIDA. *Sci. Papers Inst. Phys. Chem. Research* [Tokyo], **31** [676] 99–107 (1937).—The usual Nicol or Ahrens prism is replaced by a sheet of Polaroid. To obtain a suitable quarter-wave plate for use with the Polaroid a glass plate is uniformly stressed and placed in the optical system. Direct comparison with an apparatus employing an Ahrens prism shows that the new equipment gives satisfactory results. The transmission of the Polaroid is determined. J.B.A.

Care of shaft bearings. EDWARD INGHAM. *Brit. Clayworker*, **47** [559] 235–37 (1938).—The care of bearings is mainly a matter of insuring that they are at all times efficiently lubricated. This can be done by (1) avoiding overloading, (2) keeping the bearing properly adjusted, (3) keeping the shafting in true alignment, and (4) using a good clean lubricant suited to the purpose. All oil channels should be kept clean. The great advantage offered by colloidal graphite in reducing friction and wear of shaft bearings is referred to. R.A.H.

Determination of low humidity with the dew-point potentiometer. A. K. FRANK. *Gen. Elec. Rev.*, **41** [10] 435–37 (1938).—F. describes a dew-point potentiometer and auxiliary apparatus for making humidity determinations as low as dew points of −100°F on air, oxygen, nitrogen, hydrogen, helium, argon, neon, carbon monoxide, and methane and their mixtures. With this equipment it is easily possible to measure the humidity of gases at various points in plant distribution piping systems. The method for tests is explained and many industrial uses are enumerated. Illustrated. L.E.T.

Discharge rates from gas flowmeters. Proper temperature and pressure corrections. JOHN C. WHITWELL. *Ind. Eng. Chem.*, **30** [10] 1157–62 (1938).—W. proposes a new method of plotting discharge flow rates, for instruments of the Venturi and orifice type, against the differential manometer reading. For each of the types of meter, a sample discharge rate plot is shown as recommended. Alignment charts are given as a convenient method of calculating the groups found to be necessary in the new type of plot. Illustrated. F.G.H.

Drying with air. F. SCHOLTZ. *Ziegelwelt*, **69** [1] 10–12 (1938).—S. describes a theoretical investigation of the best method of drying with hot air. The danger of condensation is great when the hot air is used first in one drying chamber and then in another. Ways to avoid this danger are discussed. F.L.

Drying of brick. F. SCHÜNHOFF. *Tonind.-Ztg.*, **61** [46] 512–13 (1937).—S. recommends modern artificial driers in brick plants because they increase the output and improve the quality of the product and are therefore economical. W.K.

Drying machinery. FRED KERSHAW. *Ind. Eng. Chem.*, **30** [10] 1115–18 (1938).—K. briefly reviews the factors affecting the design and construction of modern scientific drying equipment. F.G.H.

Electrostatic separation: II. HERBERT BANKS JOHNSON. *Eng. Mining Jour.*, **139** [10] 42–43, 52 (1938).—J. recounts the history of the industrial application of the Huff electrostatic separation process. For Part I see *Ceram. Abs.*, **18** [1] 28 (1939). J.L.G.

Evaporation of water into quiet air from a one-foot diameter surface. B. F. SHARPLEY AND L. M. K. BOELTER. *Ind. Eng. Chem.*, **30** [10] 1125–31 (1938).—The evaporation from a 1 ft. in diameter pan of distilled water into quiet air at 53% humidity was measured for water temperatures between 63° and 93°F. The surface of the water was at the level of the surroundings. In the critical region, corresponding to a water temperature of 69.4°F, the buoyant effects of the mixture at the water surface and far away are equal. The unit evaporation rate above the critical region, in pounds/(square foot) (hour), may be expressed by the equation $e = -0.024 + 65\ (c_{vw} - c_{v\infty})$. Below the critical region the results may be expressed approximately by the equation $e = 18.75\ (c_{vw} - c_{v\infty})$, where c_{vw} is the concentration of water vapor on the gas side of the gas-liquid interface and $c_{v\infty}$ is the concentration of the water vapor in the atmosphere far from the pan, both in pounds per cubic foot. A tentative correlation with thermal free convection data has been accomplished. The ratio $Nu/Nu' = 1.29$ for $10^6 < Gr' + Pr$ (and $Gr' \times Pr' < 10^8$ agrees fairly well with the results of Hilpert determined for moist clay plates placed vertically. Acceptance of the thermal free convection-diffusional free convection analogy and generalization to other fluids is not urged until substantiated by further experimental results. Illustrated. F.G.H.

Extrusion machines. E. G. GUERRÉE. *Rev. Matériaux Construction Trav. Publics*, No. 341, pp. 17–19B (1938); translated in *Brit. Clayworker*, **47** [553] 41–42 (1938).—G. discusses a mechanical solution of the deairing process which deals mainly with the extrusion of a stiff nonplastic paste instead of a soft plastic paste. R.A.H.

For and against deairing. G. WELZEL. *Ziegelwelt*, **68**, 202 (1937); *Trans. Ceram. Soc.*, **37** [7] 55A (1938).—Following a general discussion of the problem, W. describes various constructions of machines. Illustrated. See "Vacuum—," *Ceram. Abs.*, **17** [3] 111 (1938).

Glass vapor-density balance. J. H. SIMONS. *Ind. Eng. Chem., Anal. Ed.*, **10** [10] 587 (1938).—Details of construction are given. Illustrated. F.G.H.

Grain-size distribution and statistical analysis. W. C. KRUMBEIN. *Neues Jahrb. Mineral. Geol.*, **A73**, 137–49 (1938).—The Atterberg and Wentworth grain-size classifications are compared. By the use of two logarithmic scales K. shows how ordinary statistical methods may be applied to sedimentation data. He concludes that either the Atterberg or Wentworth classification can be used because the values derived from one may be readily transformed into the other. H.I.

Practical vacuum drying. R. C. ERNST, J. W. RIDGWAY, AND F. M. TILLER. *Ind. Eng. Chem.*, **30** [10] 1122–25 (1938).—During the past decade, many investigators have contributed to the theory of air drying; relatively little work, however, has been reported on drying in vacuum. Experimental work was undertaken to determine the mechanism of drying at diminished pressure. The effects of varied conditions of temperature and pressure upon a noncompressible solid were studied. Steam shelf temperature from 100° to 130° C (212° to 266°F) and a vacuum of 18 to 26 in. of mercury were employed. Illustrated. F.G.H.

Rapid galvanometric determination of humidity in refractory bodies. M. A. POPOV. *Ogneupory*, **6** [4] 1165–69 (1938).—The method is based on the measurement of galvanic current flowing between two metallic plates connected with the refractory. The potential difference increases up to 0.6 volt in materials with a high humidity content; it depends on the size of the electrode surfaces and their inner resistance; the latter depends on the density of the material tested. M.V.C.

Screw conveyers for bulk materials handling. FRANCIS JURASCHEK. *Iron Age*, **142** [5] 28–32 (1938).—J. describes various types of commercial conveyers. Among the materials adapted to handling by screw conveyers are ground feldspar, foundry sand, silica sand, dolomite, pumice, and lime in various forms. E.H.McC.

Steam drier for a brickyard. K. SPINGLER. *Ziegelwelt*, **69** [18] 220–22 (1938).—S. discusses the necessary heating area for attaining the required quantity of heat in every drying chamber. F.L.

Thermoelectric pyrometers. B. KINKULKIN. *Stal*, **1938**, No. 6, pp. 15–19.—Optical and radiation pyrometers are generally used for high-temperature control in steel manufacture, in the firing of refractories, etc. The principle of their operation is based upon the Stefan-Boltzmann and Wien laws which are applicable to a black body. Since in practice temperature control is required for nonblack bodies, certain corrections must be added to the readings obtained with optical pyrometers. These corrections are computed from the following equation:

$$\log E_\lambda = \frac{\log \cdot C_2}{\lambda}\left(\frac{1}{T} - \frac{1}{S}\right),$$

where E_λ = emissivity for the wave length, λ, $\lambda = 0.65\mu$, log = 0.4343, C_2 (a constant of Planck) = 1.43 cm./degree, T = true absolute temperature, and S = observed absolute temperature. In the fusion of metals and the firing of refractories on their surfaces, smoke, flame, gases, etc., appear, considerably altering the reading of optical and radiation pyrometers. The studies of G. Fitterer, G. Naeser (*Ceram. Abs.*, **15** [8] 249 (1936)), K. Guthmann (*ibid.*, **16** [9] 282 (1937)), and others established that the correction which should be added to the reading of the optical pyrometer, *e.g.*, in the measurement of molten iron at 1580°C, is about 250°C; this indicates an error of about 15%. Because it is necessary to add such enormous corrections, the optical and radiation pyrometers are not suitable for measuring the temperature of the metal bath and firing of refractories (super refractories). The thermoelectric method is now used by which the temperature measuring device is in continuous contact with the research medium. K. discusses various designs of new pyrometers, referring especially to the C-SiC thermocouple (*ibid.*, **17** [3] 111 (1938)) which develops an e.m.f. of about 508 mv. at 1700°C. K. made additions of Al_2O_3, ZrO_2, and MgO to ten batches of carbon tubes to increase their mechanical and chemical properties. He constructed 15 types of nonmetallic and combined thermocouples such as C-SiC, C-W, and C-Mo, which were investigated in the Héroult, Telny, and Tamman electric furnaces. Temperature measurements were made of gases, slag, and pocket metal bath using pearlite iron, carbon steel, nickel-chrome steel, etc. To increase the durability of these tubes against the oxidizing action of the furnace gases, the effect of various putties such as Al_2O_3, ZrO_2, SiO_2, MgO, and water glass was studied. The putties of Al_2O_3 and SiO_2 guarantee the highest durability. The production process of these thermocouples, their graduation, the results of their mechanical tests, and their thermoelectric properties are described. B.E.K.

Volumetric determination of humidity in refractory bodies. A. J. Lukasch. *Ogneupory*, **6** [4] 1170–71 (1938).—The volumetric determination of moisture is based on the reaction $CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2$, by decomposing calcium carbide with water present in the refractory. M.V.C.

SEPARATE PUBLICATIONS

Instruments and devices that coal-mine officials should understand and use. G. W. Grove. *U. S. Bur. Mines Information Circ.*, No. 7037. 11 pp. Free. A description is given of water gages, anemometers, barometers, psychrometers, flame safety lamps, lamp-testing boxes, and methane, carbon monoxide, and hydrogen sulfide detectors and their use and operation in coal mines. R.A.H.

Necessity for more extended use of safety equipment in mining. D. Harrington. *U. S. Bur. Mines Information Circ.*, No. 7036. 14 pp. Free. Statistics are given on the number of people killed in mine accidents and the cost of such accidents. H. discusses legislation with respect to the use of safety equipment and machinery in mines and points out the advantages gained by using such machinery and equipment. R.A.H.

PATENTS

Apparatus for determining p_H values of solutions. E. G. Voiret. Fr. 830,713, March 26, 1937; *Chem.-Ztg.*, **62** [82] 745 (1938). D.A.B.

Apparatus for mixing clay, loam, etc. Eisenwerk Weserhütte A.-G. Ger. 663,846, July 21, 1938 (Jan. 11, 1930); 80*a*. 6.10. Mechanical details of an apparatus for mixing clay, loam, etc., are given. D.A.B.

Coating measuring device. L. A. Danse. U. S. 2,136,675, Nov. 15, 1938 (Feb. 17, 1937).

Electrically heated shaft furnace. B. G. O. Nordström (Aktiebolaget Kanthal Hallstahammar). U. S. 2,139,201, Dec. 6, 1938 (April 1, 1937). An electrically heated shaft furnace comprises superimposed brick lining the furnace wall, each brick including a projection inclined downward from the upper side of the brick and a recess below the projection for accommodating the heating element, the projection overhanging the recess and protecting the heating element from material falling through the furnace, the recess facing downwardly whereby the major part of the heat rays are directed toward the lower part of the furnace chamber, the heat rays not passing directly into the furnace chamber from the recess being reflected upwardly into the chamber by the upper surface of the projection of the underlying brick.

Equipment for removing quartz melts for further treatment. Theo. Frantz and Max Kessler (Jenaer Glaswerk Schott & Gen.). Ger. 658,614, March 17, 1938 (Jan. 15, 1937); VI/32*a*. 35. Removal of quartz melts from the furnace or form for further treatment is brought about by a grate-like receptacle, which is tilted by means of a horizontal axis and is arranged in front of a rolling train so that the melt is turned by the tilting motion of the receptacle and laid out for the rolling train. D.A.B.

Furnace for melting fine and granular substances. Arthur Sprenger (Chemische Studien-Ges. Uniwapo G. m. b. H.). U. S. 2,137,363, Nov. 22, 1938 (Nov. 2, 1937).

Grading machine. Ervin Morgan. U. S. 2,139,199, Dec. 6, 1938 (Nov. 1, 1935).

Method and apparatus for manufacturing pottery articles. R. J. Getty (A. L. Feller). U. S. 2,139,362, Dec. 6, 1938 (Aug. 11, 1936).

Pottery mold. J. E. Shultz. U. S. 2,137,359, Nov. 22, 1938 (Sept. 29, 1937).

Producing insulating material. Compagnie Française pourl' Exploitation des Procédés Thomson-Houston. Fr. 830,274, Dec. 2, 1937; *Chem.-Ztg.*, **62** [82] 745 (1938). D.A.B.

Kilns, Furnaces, Fuels, and Combustion

Experimental determination and calculation of combustion temperatures and their application to city gas. G. Ribaud. *Gas- & Wasserfach*, **81** [37] 661–66 (1938).—Formulas are developed and tables are given to calculate the theoretical and actual combustion temperature from the heat content of the gases involved; figures are given for H_2, CO, CO + H_2, CH_4, C_3H_8, C_4H_{10}, C_2H_2, and C_6H_6. See "Measurement—," *Ceram. Abs.*, **16** [1] 33 (1937). M.H.

Firing roofing tile in a tunnel kiln. Anon. *Tonind.-Ztg.*, **61** [48] 533–34 (1937).—Glazed and unglazed roof tile, previously fired in a chamber kiln, are fired in a tunnel kiln at a rate of less than 2 hr. per car and, if possible, without change of the composition of the body. To eliminate cooling cracks, however, ground brick is substituted for sand. Crawling of the glaze is reduced by faster heating up to 100°C and by tightening any leaks at the door or between the cars. W.K.

Heat balance of annular kilns. Carl Schmidt. *Tonind.-Ztg.*, **61** [43] 479–81 (1937).—S. gives a compilation and popular presentation of data published elsewhere by Claus, Hüttemann, and Rümcke. W.K.

Measurement of heat transfer by free convection from cylindrical bodies by the Schlieren method. L. M. K. Boelter and V. H. Cherry. *Heating, Piping & Air Conditioning*, **10** [10] 671–76 (1938).—The rate of convective heat transmission may be shown to determine the slope of a beam of light as it leaves the thermal field near the surface. The light beam is directed tangential to the surface at the entrance to the thermal field and the

beam slope is determined experimentally. The apparatus and method are described. Figures, tables, formulas, and derivations are given. J.L.G.

Practical hints on ring kilns. ANON. *Tonind.-Ztg.*, **62** [34] 843–44 (1938).—To increase the speed of a ring kiln, systematic experiments are necessary. Insufficient draft is the most common trouble. A thorough reparation of the kiln, elimination of cracks, and, if possible, elimination of dampness in the soil should be the first steps. Unfavorable comparison with another kiln of the same dimensions may be due to the difference in the clay and finishing temperature. A higher stack is preferable to a fan. Frequent firing or an automatic stoker is advised. The setting should not be too close; zigzag setting is best. The fire shafts should be adapted to the type of coal used and care should be taken that there is not too much accumulation at the bottom. The ware should be dry when being set. W.K.

BOOK

Gas permeability of ceramic products at different temperatures. PIERRE BREMOND. Institute de Céramique Française, Paris. Reviewed in *Verre & Silicates Ind.*, **9** [17] 200 (1938).—Ceramic mixtures have an open alveolar structure, but, with progressive vitrification, the internal microscopic closed cells are formed. Porosity is distinct from permeability which corresponds to a movement of liquid. Carbon is present in clay, arising from the decomposition of furnace gas or preëxisting in the raw materials. This carbon must escape in a gaseous form. B. studies the changes of gases through ware which are essential for firing, the kinetics of gas, the constitution of the permeable interiors, the different types of gaseous discharge, and the viscosity of gaseous fluids. The results are applied to phenomena manifest in saggers and ware during firing. The escape of gas in permeable materials does not follow one law; instead, there are several types of discharge. The law of Poiseuille completed by Sutherland (viscous discharge) was exact up to 1000°. Material with a coarse structure, such as saggers, shows this type of discharge. Material with a very fine structure has a molecular type of discharge. The relation of the diameter of the capillaries to the free course of the molecules influences the distribution of the discharges. A "permeameter" devised by B. permits the calculation of the percentage when cold of the viscous and molecular outflow. It is then possible to deduce the behavior when hot of the substance studied in the presence of furnace gas. M.V.C.

PATENTS

Extracting hydrogen gas or gas rich in hydrogen from technical gases such as coke-oven gas. RUHRCHEMIE, A.-G. Ger. 657,067, Feb. 10, 1938 (Feb. 6, 1935); IV*b*/12*i*. 1,01. The gas mixture, which contains one or more heavy adsorbable gases in addition to the hydrogen, is passed over activated carbon. D.A.B.

Tunnel kiln. M. E. GATES. U. S. 2,138,851, Dec. 6, 1938 (April 6, 1936). (1) In a tunnel kiln the combination comprises an annular traveling floor composed of a plurality of floor segments, refractory brick surfacing the floor, metallic supporting members for the floor having webs capable of material deflection inclined toward the axis of the floor, whereby the weight of the load on the floor sets up a component of force directed toward the axis of the floor. (3) The method of creating a counterflow of hot gases toward the entrance end of a tunnel kiln having a rotating annular floor and adapted to fire brick, block, etc., which is characterized by arranging the brick or block on the rotating annular floor of the kiln in rows inclined in a direction opposite to that of the travel of the floor through the kiln and directing the flame from the heating burners against the inclined faces of the ware and thereby directing the gases toward the entrance end of the kiln.

Tunnel kiln. T. G. MCDOUGAL (General Motors Corp.). U. S. 2,137,091, Nov. 15, 1938 (Jan. 4, 1936).

Geology

Aluminous hydrosilicates on the margin of clays. V. CHARRIN. *Céram., Verrerie, Email.*, **6** [4] 118–20 (1938).—Allophane ($SiO_2 \cdot Al_2O_3 \cdot 5H_2O$) with a high alumina content and pyrophyllite ($4SiO_2 \cdot Al_2O_3 + nH_2O$) with a high silica content originated from the decomposition of anhydride aluminous silicates; they are too rare to be used industrially. Zeolites are hydrated feldspars in which the aluminum silicate (also hydrated) is combined with a hydrosilicate of a protoxide, either lime, potash, soda, or baryta. Zeolites are used for purifying water. Montmorillonite ($4SiO_2 \cdot Al_2O_3 \cdot 2H_2O$) has a high silica content and is used in heavy ceramics. Properties of these types of clays are given. M.V.C.

Atomic arrangement and variability of the montmorillonite group. G. NAGELSCHMIDT. *Mineralog. Mag.*, **25** [162] 140–53 (1938).—The montmorillonite group is shown to have the end-members montmorillonite, nontronite, and magnesium beidellite which, on the dehydrated basis, have the formulas $Al_2Si_4O_{11}$, $Fe_2Si_4O_{11}$, and $Mg_2Si_4O_{11}$, respectively. One montmorillonite, two beidellites, two nontronites, and one Mg beidellite were studied in detail. Their isomorphous replacements are calculated on the basis of 11 oxygen atoms, and the excess cations are found to balance the negative charges resulting from the replacements. Base-exchange determinations show that all excess cations are exchangeable in three of these materials, but that, in the case of Mg beidellite, there are discrepancies. The hypothesis is made that a certain amount of isomorphous replacement of silicon by aluminum and perhaps of aluminum by magnesium is essential for this structural type and may explain both the high water content, which is due to the excess cations, and the poor diffracting power for X-rays, which is due to lack of regularity of the lattice. All the samples studied belong to the same structural type. X-ray powder data show that the replacement of Al by Fe and Mg within the lattice causes an increase in the lattice dimensions and, for air-dry material, a decrease of the intensities of (003) and (005). H.I.

Base-exchange equilibria in soil profiles. R. L. MITCHELL. *Jour. Agr. Sci.*, **27** [4] 557–68 (1937).—The principal factors affecting cationic migration in soil complexes are (1) properties of cations initially responsible for the exchange reactions, (2) nature of the adsorbed cations and their relative amounts in the exchange complex, (3) nature of the exchange complex, and (4) the position on the surface of the complex at which exchange is taking place. The general principles of base exchange are considered, including (1) the order of ease of entry and displacement in individual cationic series; (2) the degree of hydration of respective cations of the series; (3) the effect of cationic size; (4) the effect of valency; (5) the anomalous position of hydrogen in the univalent cationic series of ease of entry order $H > Cs > Rb > K$, $NH_4 > Na > Li$; (6) the effect of metastructure as shown in investigations of permutites, bentonites, and kaolinite clays; and (7) the double-layer phenomena. The exchangeable cation contents of six soil profiles at various depths up to 165 cm. below the surface were determined. Results included exchange capacity, clay content, and p_H values for Ca, Sr, Mg, Na, K, and H. Cation displacement occurs as a result of the downward movement of hydrogen ions from the surface layers, and a layer of minimal basic cation content exists at a depth of about 30 cm. Below this, the basic cation content increases once again, but the base-exchange capacity follows the clay content fairly closely. Calcium and strontium are displaced and readsorbed at similar rates in accordance with their exchange constants, although there is about 400 times as much calcium as strontium present. The be-

havior of the other cations also appears to be in accordance with the theoretical considerations. See *Ceram. Abs.*, **16** [11] 349 (1937). P.S.D.

Base exchange and its problems. A. BRAMMALL AND J. G. C. LEECH. *Sci. Jour. Roy. Coll. Sci.*, **8**, 43–51 (1938).—The mechanism of base exchange is dealt with. If Si atoms are partly replaced by Al atoms, the excess negative charges on the Si layers could be satisfied by (1) the unloading of surplus negative charges, effected by commuting O_2 to $(OH)_2$; (2) a compensatory increase in the positive charge on the Al layer, *e.g.*, addition of Mg; and (3) the attachment of outer cations equivalent to the excess negative charges. Replacement of Al atoms in the Al layer by divalent atoms would be similar in its effect. Marshall's conclusion (*Ceram. Abs.*, **16** [11] 352 (1937)) that the exchangeable bases form an integral part of the framework lattice is thus adopted. The liberation of Al and Fe''' on treatment with saline solutions is discussed. The breakdown of the crystal lattice is favored and a possible alternative mechanism is given, but the possibility that exchangeable bases include complex cations containing both Al and Fe''' is under investigation by the authors. Attention is called to hydrolysis of mineral dust, and it is suggested that many anomalies associated with base-exchange phenomena in clays may rest in obscure mineral changes induced by the aqueous solutions actually used in base-exchange determination. N.M.S.

Bauxite occurrences at Reichenau in Bohemia. ALEXANDER ORLOV. *Neues Jahrb. Mineral. Geol.*, **A74**, 251–78 (1938). H.I.

Bentonite deposits in the Far East. ANON. *India-Rubber Jour.*, Sept. 4, 1937; abstracted in *Chem. Trade Jour.*, **101**, 230 (1937).—Analyses of four deposits of Japanese bentonite are given. The best, found in Hokkaido, occurs in a seam 300 ft. thick, under coal. It is pure white and free from foreign matter. It takes up 5 times its dry weight of water and swells to 6 to 8 times its bulk. See *Ceram. Abs.*, **17** [3] 115 (1938). L.R.B.

Boron derivatives in the ceramic industry. A. ESME. *Argile*, No. 184, pp. 19–21 (1938).—Boron constitutes about $^1/_{100,000}$ of the earth's crust and is concentrated in the form of borates and borosilicates, about 30 of which have been identified. Some crystallized natural borates and their formulas are as follows: (1) borax or tincal, $B_4O_7Na_2 \cdot 10H_2O$ or $Na_2O \cdot 2B_2O_3 \cdot 10H_2O$, containing 36.5% boric anhydride in pure form; (2) kernite or rasonite, $B_4O_7Na_2 \cdot 4H_2O$ or $Na_2O \cdot 2B_2O_3 \cdot 4H_2O$, containing 51% boric anhydride but deficient in water; its crystals show efflorescence in air; (3) ulexite, $Na_2O \cdot 2CaO \cdot 5B_2O_3 \cdot 16H_2O$, containing 43% B_2O_3; (4) larderellite, $B_5O_8NH_4 \cdot 2.5H_2O$; (5) colemanite, $B_6O_{11}Ca_3 \cdot 5H_2O$ or $2CaO \cdot 3B_2O_3 \cdot 5H_2O$; (6) boronatrocalcite, $B_5O_9 \cdot NaCa \cdot 8H_2O$; (7) priceite or pandermite or borocalcite, $5CaO \cdot 6B_2O_3 \cdot 9H_2O$; (8) boracite, $5MgO \cdot 7B_2O_3 \cdot MgCl_2$ (the richest, with 62% B_2O_3); (9) pinnoite, $B_2O_4Mg \cdot 3H_2O$; (10) ascharite, BO_3HMg; (11) heintzite, $B_{11}O_{19}Mg_2K \cdot 7H_2O$, etc. These and other borates can be prepared in the laboratory, and experiments to reduce these salts to a certain number of more or less hypothetical boric acids are being made. According to Hackspill it is more rational to start with the structural formula of ordinary boric acid and concede that several molecules can unite, with the elimination of water. The ceramic industry uses boric acid or borax, which is soluble, although insoluble borates form ceramic colors of great interest. A table shows the colorations obtained by the fusion of oxides or metallic salts with borax in oxidizing and reducing mediums. M.V.C.

Chromite. ANON. *Mineral Ind.*, **46**, 89 (1937).—The consumption of chromite in the industries of the U. S. is estimated to be as follows: refractory 40, metallurgical 45, and chemical 15%. The chief sources of refractory ore imported during 1937 were Rhodesia, Cuba, Greece, and the Philippines. Production in the U. S. amounted to 2321 long tons, derived chiefly from the California and Oregon deposits. B.C.R.

Crystal structure of montmorillonite. E. MAEGDEFRAU AND U. HOFMANN. *Z. Krist.*, **98**, 299–323 (1937).—X-ray investigations were carried out on three samples of montmorillonite from different sources and on one synthetic magnesium silicate with a montmorillonite structure. A reflection with d approximately 3 Å corresponds with the (001) plane and has the index (003), (004), (005), or (006), depending on water content. The intensity calculated on the basis of "swelling" water content showed a good correspondence with observed intensity. All reflections have rhombic (00l) and (hk0) indices, (hkl) reflections being absent. The structural layers are separated by H_2O groupings and show no orientation in the a and b directions. The pyrophyllite-like atom distribution in the individual layers permits an approximate calculation of the intensities of the (hk) reflections. H.I.

Fire clay. F. J. NORTH. *Times Trade & Eng.*, **44** [897] 30 (1938).—In Wales, fire clay occurs in association with the coal-bearing strata, but in North Wales it is not in actual contact with coal seams. N. gives the occurrences of fire clay and the chief uses of fireclay products. A.B.S.

Fire clays and shales in Northumberland and Durham. ANON. *Times Trade & Eng.*, **43** [896] 6 (1938).—Fire clays in Northumberland and Durham are usually the underclays of coal seams and are won along with the coal. For coke ovens and gas retorts, fireclay brick have been largely replaced by silica brick. Some shales are used for salt-glazed pipes, tile, and brick. The bituminous shales can be pulverized and used for raising steam. The shales now most important in this district are the seat of the Cleveland ironstone. The fine-grained highly siliceous sandstones of the ganister type, particularly abundant in the lower Coal Measures of South Tyne, Derwent, and Wear, are extensively worked for the manufacture of silica brick which are used in the construction of steel furnaces, coke ovens, and gas retorts. A.B.S.

Flotations separations of nonmetals. OLIVER C. RALSTON. *Chem. & Met. Eng.*, **45** [5] 268 (1938).—Ceramic raw materials such as clay, feldspar, quartz, talc, nephelite, and spodumene can be beneficiated by levitative processes. Most materials in this group demand filming agents wherein the filming ion is the cation. The substituted ammonium compounds and nitrogen bases are the best of this class of filmers developed; in each instance, they tend to film the acidic minerals such as quartz, feldspar, mica, and other silicates. Short-chain amines are best for clays, while long-chain substituents are best for quartz. Fractionating clays into ceramically different parts followed by proportioned mixing to gain control over shrinkage, vitrification range, etc., is now possible. See *Ceram. Abs.*, **17** [4] 150 (1938). B.C.R.

Italian bentonite. V. CHARRIN. *Céram., Verrerie, Email.*, **6** [5] 148–51 (1938); *Argile*, No. 184, pp. 1–5 (1938).—Italian bentonite mined on the Isle of Ponza in the Pontine Islands is white and is in a very finely divided state which gives exceptional porosity. It is slightly more siliceous and less aluminous than the American bentonite and when dried at 100°C it contains silica 69.5, alumina 16.5, iron oxide 0.7, lime 2, magnesia 1, and soda and potash 1%; loss on firing is 9.30%. The deposit represents 2 million tons and originated from the devitrification of volcanic rock. Bentonite is used principally as adjuvant; it improves the quality of fine and heavy ceramic mixes and it is used in the preparation of abrasives. In small quantities in the enamel batch it keeps the particles of enamel in supension. At about 700°C the special properties of this earth are lost. Because of its whiteness and low iron oxide content, Italian bentonite can be used in porcelain manufacture; this has not been attempted with American bentonite. M.V.C.

Mineral materials for foundry uses from Bassin d'Uzès (Gard). ANON. *Rev. Fonderie Moderne*, **32**, 257 (1938).—Refractory clays with an average of 20 to 22% and a maximum of 36% alumina are found in this district in close proximity to white and yellow sands. Molding sands, refractory lining materials, and a pseudokieselguhr are made from them. The foundry sand has a refractoriness of 1685°C. The lining material is good for cupolas, ladles, converters, stills, and high-temperature

furnaces. The artificial kieselguhr, besides being used for the usual heat insulation, is also employed for sound insulation. The methods for preparing the clays and sands for the three purposes are briefly described. M.H.

Potash-soda feldspars: II, Applications to petrogenesis. EDMONDSON SPENCER. *Mineralog. Mag.*, **25** [162] 87–117 (1938).—The common occurrence of the microcline form of potash-soda feldspar in pegmatites may be due to the crystallization temperature of pegmatites falling within the perthite ex-solution range. Modifications in existing crystallization diagrams are made to permit a hypothetical separation of residual granitic magma into two fractions, one rich in potash, producing ordinary pegmatites, and the other rich in soda, producing complex pegmatites and possibly much of the myrmekite of granite. For Part I see *Ceram. Abs.*, **16** [8] 257 (1937). H.I.

Preparation of bauxites for microscopic study. E. P. LEVANDO AND N. A. ADAMOVA. *Zapiski Vserossiĭskogo Mineral. Obschchestva*, **66**, 713–19 (1937); abstracted in *Chem. Zentr.*, **1938, II**, 1556.—The solubility of natural diaspore and synthetic gibbsite in HCl and oxalic acid was studied. While gibbsite showed a rising solubility proportional to the HCl concentration, the solubility of diaspore in HCl is practically equal to zero, at least up to a concentration of 18%. The solubility of gibbsite in oxalic acid increased up to 3% concentration (about 1%); it did not increase with higher oxalic acid concentration. Bauxite can be pulverized better in alcohol than in water as grinding is two and one-half times as rapid. M.V.C.

Resources of clay. V. CHARRIN. *Argile*, No. 181, pp. 1–5 (1938).—C. discusses the rapid exhaustion of certain French deposits. Clay is found in all geological strata except the crystalline; it forms the base of numerous sedimentary formations, though, in many instances, aging and metamorphosis have not completely transformed it. Clays having the desired plasticity abound especially in tertiary terranes, while quaternary terranes are the main source of the heavy ceramic industry. Argillaceous deposits in the process of formation by decomposition of feldspathic rock or by alluvial and marine deposition are discussed. M.V.C.

Silica rock. F. J. NORTH. *Times Trade & Eng.*, **44** [897] 30 (1938).—The silica rocks (ganister) in Wales consist mainly of grains of quartz cemented by additional quartz deposited between them. They are chiefly obtained from the Millstone Grit formation. The material is abundant but is only worked where transport facilities (roads and railways) cross the outcrop. Occurrences are briefly mentioned. A.B.S.

Silicate and related systems involving chemical components of Illinois sedimentary rocks. F. V. TOOLEY. *Trans. Illinois State Acad. Sci.*, **30** [2] 194–97 (1937). B.C.R.

Variation diagrams for groups of igneous rocks. ESPER S. LARSEN. *Jour. Geol.*, **46** [3, Pt. II] 505–20 (1938).—A modified variation diagram for plotting groups of chemical analyses of related igneous rocks is proposed. The major constituents (SiO_2, Al_2O_3, total iron + Mn as FeO, MgO, CaO + BaO + SrO, Na_2O, and K_2O) are adjusted so that their sum is 100. The position of the rock is determined by the average of the major oxides as one-third $SiO_2 + K_2O - FeO - MgO - CaO$. Relatively uniform variation diagrams result, and they characterize the rocks of the province. In a triangular diagram, two groups of normative minerals are plotted as two points and are joined by a line. For one group, normative or-ab-an are used. Feldspathoids are calculated to feldspar by adding SiO_2; they are then added to the feldspar, and the total is adjusted to 100. For the other group, total feldspar (with feldspathoids adjusted to the feldspar added), femic constituents (olivine adjusted to pyroxene), and quartz or deficient SiO_2 are plotted. In these plots, the position of the lines and their slopes and lengths are all significant. Plots of analyses from a petrographic province show a systematic arrangement of lines and points but some analyses are erratic. They also bring out systematic differences between petrographic provinces. The plotted points for most petrographic provinces of the lime-alkalic series begin with basalts (47% SiO_2) and end with rhyolites (77% SiO_2). In such provinces, especially for lava fields, the total amount of normative feldspar in most rocks is about 65% and the amount of albite in the feldspar is about 47%. A.C.B.

What is hardness? G. DERGE. *Ind. Heating*, **5** [11] 1011–14 (1938).—D. surveys the views expressed on the nature of hardness of a material and the practical means developed to measure it. Attempts have been made to correlate it with other physical properties. Meyer's Law expresses its connection with compressibility and the energy expended in the measurement. Hardness is about the same on all crystal faces, and it is considered as the resistance to deformation as measured by the true strain-stress curve determined in tension or compression tests. Hardness as defined and determined today is useful only as a means for controlling uniformity of structure and quality. M.H.

BOOKS AND SEPARATE PUBLICATIONS

Flotation and agglomerate concentration of nonmetallic minerals. OLIVER C. RALSTON. *U. S. Bur. Mines Repts. Investigations*, No. 3397, 63 pp. Free. See *Ceram. Abs.*, **17** [4] 150 (1938). R.A.H.

Geology and Mineral Resources of the Honeybrook and Phoenixville Quadrangles in Pennsylvania. FLORENCE BASCOM AND G. W. STOSE. *U. S. Geol. Survey Bull.*, No. 891, 145 pp. Govt. Printing Office, Washington, D. C. Price 65¢. A description is given of the topography, areal geology, geologic structure, geologic history, and mineral resources of an area in the Piedmont province of southeastern Pennsylvania. A detailed geologic map and cross sections are included. The chief mineral resources are stone, lime, white clay, and sand. R.A.H.

Mineral Industry, 1937. G. A. ROUSH, editor. McGraw-Hill Book Co., Inc., New York. 766 pages. Price $12. Reviewed in *Eng. Mining Jour.*, **139** [10] 81 (1938).—The preface contains a review of the mineral industry from 1913 through 1937. The current volume covers the minerals and metals from "abrasives" to "zinc." More than 30 authorities contribute. Each commodity is treated with respect to source, production, price, trade, technology, and use. J.L.G.

Shrewsbury District. R. W. POCOCK, T. H. WHITEHEAD, C. B. WEDD, T. ROBERTSON, ET AL. *Geol. Survey Gt. Brit., Mem. Geol. Survey England.* Price 5s net. The quartzites, sands, gravels, fire clays, brick clays, and other minerals and their locations are briefly described, and their economic uses are stated. A.B.S.

PATENT

Treatment of clays. GOONVEAN & ROSTOWRACK CHINA CLAY CO., LTD., AND L. E. B. PEARSE. Brit. 495,174, Nov. 23, 1938 (June 3, 1938).

Chemistry and Physics

Accelerating and making more precise the mechanical analysis of clays by the Sabanin method. I. E. DUDAVSKIĬ. *Zavodskaya Lab.*, **7**, 487–88 (1938).—The disintegration of lumps of clay matter is effected by boiling the sample before analysis in sodium oxalate, $Li_2C_2O_4$, or Na_2HPO_4. A sedimentation of the solution is then undertaken in a glass with a syphon installed 2 cm. from the bottom of the glass. The level of the liquid is held at 8 to 10 cm. from the bottom; therefore, the first decantation takes place in 300 to 400 sec. instead of 100 sec. Further decantations are undertaken at the usual intervals. By this method, the sedimentation of fractions under 0.01 mm. takes 1 to 1.5 hr. instead of 4 to 6 hr. P.B. & E.S.

Aluminum carbide, Al_4C_3, and aluminum carbonitride, Al_4C_2N. M. VON STACKELBERG, E. SCHNORRENBERG,

R. PAULUS, AND K. F. SPIESS. *Z. Physik. Chem.*, **A175** [1] 127–30 (1935).—The combination of Al_3C_3N is formed at 1800°C. Its appearance and properties can hardly be distinguished from the carbide Al_4C_3. The carbonitride corresponds to an intermediate step in the nitration of the carbide to the nitride: $5Al_4C_3 + 10N_2 \rightarrow 4Al_3C_3N + 3C + 8N_2 \rightarrow 20AlN + 15C$. The conditions of formation and the properties of Al_3C_3N and Al_4C_3 are discussed. Al_4C_3 takes on excess Al at high temperature and liberates it on cooling. The carbides Al_9C_3 and Al_3C_2 are finely dispersed mixtures formed in this manner. Al_2O_3 at room temperature is also a mixture of Al and corundum. The so-called amorphous Al_4C_3 is identical with the crystalline. L.E.T.

Application of Hahn emanation method for investigation of reactions in the solid state: III, Formation of $PbSiO_3$ from PbO and SiO_2. ROBERT JAGITSCH. *Z. Physik. Chem.*, **B33,** 196–200 (1936).—The formation of $PbSiO_3$ from PbO and SiO_2 at temperatures between 500° and 700°C has been investigated by the Hahn emanation method. The speed of reaction is first determined by the amount of diffusion of the PbO in the direction of the SiO_2 and then, with further heating, by the diffusion of the PbO molecules through the already formed $PbSiO_3$. At 500°C an exchange effect is hardly noticeable; with an increase in temperature the diffusion of the PbO (melting point 879°C) is constantly increased and the reaction takes place. The mixture looks light yellow at 600°C, but at 700°C, the color is greenish yellow and the compound is sintered and has a glassy surface. The results on heating the mixture $PbO + SiO_2$ are graphically presented; the *EV* (emanation ability) against time in minutes at temperatures from 500° to 700°C is given. After the mixture is heated for 1 hr., the *EV* (taken as 100% at the start) is 85 at 500°, 40 at 600°, and 25% at 640°C; at 700°C the value has dropped to less than 5% of the starting value. 3 diagrams. **IV, Kinetics of the formation of calcium silicate.** *Ibid.*, **B36,** 339–46 (1937).—The reaction between CaO and precipitated SiO_2 in a molecular proportion of 1:1 was investigated by the Hahn emanation method at temperatures between 775° and 1091°C. The precipitated silica was indicated with radiothorium. The course of reaction is shown mathematically by the Wurzel-Zeit-Gesetz (radical-time-law). The reaction takes place in two parts: (1) a surface reaction, and (2) diffusion of the CaO molecules through the already formed silicate. The activation energy for both processes is equal to 23.2 Cal. A strong increase in the speed of reaction occurs above 900°C at the transformation of α-quartz into tridymite. J. gives 8 diagrams showing the log of *EV* against time at the various temperatures. See "Reactions—," *Ceram. Abs.*, **16** [1] 45; [2] 75 (1937). L.E.T.

Crystallized chemical compounds in the system lead oxide–silica. N. N. VALENKOV AND E. A. PORAĬ-KOSHITZ. *Zhur. Fiz. Khim.*, **6,** 757–61 (1935); abstracted in *Sprechsaal,* **70** [47] 590 (1937).—X-ray studies of melted mixtures of the system lead oxide–silica detected the existence of compounds Pb_2SiO_4 and $PbSiO_3$. No traces of compounds Pb_3SiO_5 and Pb_2SiO_7 were found; all mixtures containing up to 40 mol. % silica contained only orthosilicate and free lead oxide or orthosilicate and metasilicate. M.V.C.

Determination of carbon and hydrogen on micro- or semimicro-samples with one compact and movable apparatus. SAMUEL NATELSON, S. STEVEN BRODIE, AND EDWIN B. CONNER. *Ind. Eng. Chem., Anal. Ed.*, **10** [10] 609–12 (1938).—A compact and movable outfit is described for the determination of carbon and hydrogen on samples ranging from 2.5 to 35 mg. An analytical or microbalance may be used, depending upon the amount of material that is available. Little more time is required for the determination of the semimicrosample than for that of the microsample. An aspirator is described for conditioning the absorption tubes. Precipitated silver is used in the combustion tube to hold back large amounts of halogen. Illustrated. See *Ceram. Abs.*, **17** [10] 336 (1938). F.G.H.

Direct determination of sodium oxide in feldspar. E. W. KOENIG. *Jour. Amer. Ceram. Soc.*, **22** [1] 24–31 (1939).

Effect of particle size on plasticity of kaolinite. H. WHITTAKER. *Jour. Amer. Ceram. Soc.*, **22** [1] 16–23 (1939).

Electron diffraction and surface form. W. COCHRANE. *Sci. Jour. Roy. Coll. Sci.*, **8,** 73–80 (1938).—The surface form of a crystal can be found by electron diffraction patterns. N.M.S.

Estimation of copper, zinc, and cobalt (with nickel) in soil extracts. P. L. HUBBARD. *Ind. Eng. Chem., Anal. Ed.*, **10** [10] 615–18 (1938).—An elaboration of dithizone methods is adapted to the examination of soils and similar materials. See "Dithizone—," *Ceram. Abs.*, **17** [8] 291 (1938). F.G.H.

Investigations of the electrical conductivity of some basic elements, binders, and their mixtures for the manufacture of insulating substances for electrical heating elements. K. BACKHAUS. *Elektrowärme,* **8** [10] 261–66 (1938).—Different kinds of magnesia, Al_2O_3, beryllium oxide, zirconium oxide, white clay, SiO_2, kaolin, soapstone, corundum with 99% Al_2O_3, and Mg oxide were used in powder form under pressure and as fired pastes; the electrical conductivity was determined as a function of temperature. For each material and some mixtures, the respective curves are given between 200° and 1000°C for pressures up to 100 kg./cm². M.H.

Manganese and its compounds. A. ESME. *Argile,* No. 187, pp. 5–11 (1938).—Manganese is a grayish brilliant metal with yellow and reddish reflections. It is very hard and heavy (specific gravity 7.2); it melts at 1250°C. Before it was discovered by Kaim in 1770, it was considered an iron. Under the name of "black magnesia," pyrolusite was used, up to a certain amount, as a decolorant of glass and, in larger amounts, as a colorizer. The most important manganese minerals are (1) pyrolusite, MnO_2 with 63.6 Mn and 36.3% O, the principal natural mineral of manganese, usually containing impurities; (2) psilomelane, a hydrated dioxide with the variable composition $4MnO_2 + MnO + nH_2O$, sometimes considered a multibasic manganate, (Mn, Ba, K_2)O + $4MnO_2$; (3) braunite, Mn_2O_3, a hard compact metal with impurities which on crystallizing forms brilliant gray tetragonal pyramids; (4) manganite, a hydrated sesquioxide, $Mn_2O_3 \cdot H_2O$; (5) haussmanite or red oxide, Mn_3O_4; (6) wad or warwicite, also called peat or turf manganese, a variable compound $nMnH_2 + mMnO + pH_2O$. The principal chemical salts derived from manganese are (1) manganous oxide, MnO, a green powder obtained by the reduction of other oxides, soluble in acids and not soluble in water; (2) manganous hydrate, $Mn(OH)_2$; (3) manganous chloride, $MnCl_2$, in the form of rose crystals formed during the manufacture of chlorine and used in dyeing; (4) manganous sulfate, $MnSO_4$, used for coloring porcelains; (5) manganous sulfide, MnS, with a characteristic pale flesh rose color; (6) manganic oxide, Mn_2O_3; (7) manganic hydrate, $Mn(OH)_3$; (8) manganous-manganic oxide, Mn_3O_4, the most stable oxide; (9) manganic sulfate, $Mn_2(SO_4)_3$, dissolved in water, gives a dark red liquid; (10) manganese persulfate, $Mn(SO_4)_3$, a powerful oxidizer; (11) manganese dioxide or peroxide, MnO_2, analogous to natural pyrolusite; in glassmaking it acts as colorant in large amounts and as decolorant by oxidizing impurities which color glass, especially green ferrous oxide, forming the less intensely colored yellow oxides; with the silicate of Mn it forms violet which eliminates the yellow by complementary coloring; (12) permanganic anhydride, Mn_2O_7, a powerful oxidizer; (13) manganate, MnO_4X_2, and permanganates, MnO_4X; (14) potassium permanganate, $KMnO_4$, soluble in water, giving an intense violet colored solution which is highly oxidizing. The manganate derived from the permanganate gives a green solution which explains the name "chameleon mineral" given to this product. Mn compounds are used in glassmaking to reduce the refining period and to augment fluidity (2.5% MnO). The thermic expansion diminishes when the proportion of MnO increases, and the resistance of glass

to corrosion by alkalis is improved. As colorant, larger amounts of manganese silicate give violet as does $Mn_3(PO_4)_3$. For porcelain and stoneware, manganese is chiefly used to obtain rose coloring. The analysis of a colorant producing rose is alumina 81.16, phosphoric acid 9.44, and manganous oxide 9.57%. The firing atmosphere should be slightly oxidizing. In metallurgy, manganese is invaluable as a refiner of steels, etc. M.V.C.

Organic reagents in qualitative analysis: III, Analysis of the common metals of the alkaline earth group and magnesium using 8-hydroxyquinoline. LEO LEHRMAN, M. MANES, AND J. KRAMER. *Jour. Amer. Chem. Soc.*, **59** [5] 941–42 (1937).—Using tannic acid, 1 mg. of alkaline earth metals can be detected even in the presence of large amounts of ammonium salts. Using 8-hydroxyquinoline, 1 mg. of Ca^{++} and Mg^{++}, 2 mg. of Ba^{++}, and 3 mg. of Sr^{++} can be detected in the presence of 500 mg. of any other metal of this group or combination of others. Ca^{++} and Mg^{++} are separated from Ba^{++} and Sr^{++} by precipitating them with 8-hydroxyquinoline in an ammoniacal solution. The Ca^{++} is separated from Mg^{++} as oxalate in acetic acid, and the magnesium is reprecipitated as the 8-hydroxyquinoline salt by making it alkaline with ammonia. Ba^{++} and Sr^{++} are then analyzed. F.G.H.

Polarographic method of determining iron in ores and metallurgical slags. YU. S. LYALIKOV. *Zavodskaya Lab.*, **7**, 394–99 (1938).—The determination of trivalent iron is conducted in an ammonia medium from tartaric and citric acid complexes. The presence of calcium, manganese, and aluminum does not influence the results obtained. P.B. & E.S.

Preparation and properties of the higher oxides of lead. G. L. CLARK, N. C. SCHIELTZ, AND T. T. QUIRKE. *Jour. Amer. Chem. Soc.*, **59** [11] 2305–2308 (1937).—The oxides Pb_3O_5 and Pb_5O_8 were prepared by a pressure bomb technique at temperatures of 260° to 275°C and 295 to 310°C, respectively. These were identified by microscopic examination and X-ray diffraction patterns. The large crystals obtained by Simon and reported to be pure PbO_2 are identical with the Pb_2O_3 crystals prepared in this work. Pb_3O_4 in the form of very large crystals was also prepared in the bomb at 355° to 375°C and is identified by its X-ray pattern. A new lead-sodium-oxygen compound is also prepared in the bomb. Illustrated. F.G.H.

Qualities of the border surfaces. J. A. HEDVALL. *Tek. Tid.*, **68C** [5] 33–36; [6] 41–46 (1938).—H. states that, in many cases, it is not a resistance of the particle surface which is desired but a high capacity of activity against the adjacent particle. He discusses the effect upon this activity of the structure of the particle, incorrect crystallographic reconstruction, conversion in new crystalline systems, contact between particles of two crystalline systems, changes in the magnetic and electric state of the material, catalyzing by illuminating, and ultrasound oscillations. Many examples show the possibilities of improving the activity of the border surfaces and, through this, the velocity of many reactions. F.L.

Reaction between solid magnesia and silica. I. G. BUBENIN. *Stroitel. Materialy*, **1937**, No. 3, pp. 53–56.—A chemical interaction takes place between MgO and SiO_2 when heating mixtures of $MgCO_3$ and SiO_2 in the molecular ratios $MgO:SiO_2$ = 0.5:1, 1:1, 1.5:1, and 2:1 in the temperature interval 1020° to 1200°. The heating curves show no exothermy. At 1020° the reaction velocity is slight. With the increase of temperature to 1200° it increases, leading to an increase of soluble SiO_2 in the product. The reactivity of MgO and SiO_2 in the above temperature interval depends on the MgO content; with its increase the reaction takes place more quickly and a greater amount of SiO_2 goes over to a form soluble in 5 and 10% *N* HCl solution. When heating for 1 hr. at 1200° in mixtures with $MgO:SiO_2$ = 0.5:1, 1:1, and 1.5:1, grains with a refractive index of 1.685 ± 0.005 appear, and the crystallization process begins. In the 2:1 mixture this process is more evident and the anisotropic aggregates have a feeble birefringence and a refractive index of 1.661 ± 0.005, which corresponds to that of clinoenstatite. P.B. & E.S.

Research upon the system $CaO–Al_2O_3–Fe_2O_3$. B. TAVASCI. *Ann. Chim. Applicata*, **27** [16] 505–18 (1937).—T. begins his study of the ternary system with the components $CaO·Al_2O_3$, Al_2O_3, Fe_2O_3, and $CaO·Fe_2O_3$. The experimental procedure and results of his study of the binary systems $CaO–Al_2O_3$ and $CaO–Fe_2O_3$, beginning with $CaCO_3$, Al_2O_3, and Fe_2O_3 (products of separation according to Kahlbaum), are given together with 4 graphs and 16 photomicrographs of mineralogical sections whose components are under treatment and discussion. For the parts of the ternary system studied, T.'s conclusions show the following temperature intervals: (1) the temperature below which the constituent (gamma) was unstable, (2) the interval at the beginning of which the constituent (gamma) indicated a stable outcome, and (3) the temperature at which the constituent (gamma) went into solution. These intervals are correlated with the pertinent chart or photomicrographs. The inaccuracies of Americans who have worked in the related zone are pointed out in processes given. From these data the following are found to exist: (1) a eutectic binary, alpha-beta, termed by Hansen, Brownmiller, and Bogue as eutectic Ca-CF; and (2) a eutectic gamma-beta, and hence a field much more restricted for the segregation of the constituent (gamma). The presence of two eutectic ternarians (alpha, beta, and gamma and gamma, beta, and CF) should be observable; particular indications prove this. One of these went into complete solution with the composition found by McMurdie (*Ceram. Abs.*, **16** [6] 189 (1937)). Diagrams show the qualitative stability at certain temperature intervals, the final diagram representing the equilibrium of fusion. K.R.

System water–boron oxide. F. C. KRACEK, G. W. MOREY, AND H. E. MERWIN. *Jour. Wash. Acad. Sci.*, **28**, 461 (1938).—The crystalline phases in this system are ice, H_3BO_3, three modifications of HBO_2 which are monotropically related, and B_2O_3. The solubility curve for ice extends only from the melting point to the cryohydric point at −0.76°C. The curve for H_3BO_3 rises smoothly from this point to a maximum at the melting point (metastable) of H_3BO_3 (170.9°C) and then descends to end at the metastable eutectic HBO_2 III and H_3BO_3. The three forms of HBO_2 melt congruently; HBO_2 I, the stable modification, melts at 236°C, and HBO_2 II and HBO_2 III, both metastable, melt at 200.9°C and 176.0°C, respectively. Their solubility curves have flat maxima at the composition HBO_2. The curve for the stable form, HBO_2 I, intersects the curve for H_3BO_3 at 169°C, at which point H_3BO_3 decomposes to form HBO_2 I and a solution of equilibrium composition. The reaction is abnormally sluggish, so that the metastable continuation of the solubility curve of H_3BO_3 is realized as if HBO_2 I did not exist. The curves of HBO_2 II and HBO_2 III intersect that of H_3BO_3 at metastable eutectics at 169.6°C and 158.5°C, respectively. Crystalline B_2O_3 melts at 450 ± 2°C. It has been crystallized from solutions in sealed tubes, as well as in open vessels. The solubility curve extends from the melting point to the intersection with the curve of HBO_2 I at 235°C and with that of HBO_2 II at 200°C. Both these points are eutectics, the second being metastable. The latent heat of fusion of B_2O_3 is calculated to be 97 cal./g. Contrary to prevalent supposition, B_2O_3 can coexist in the crystalline form with solutions at a considerable pressure of water vapor, this being nearly 3 atm. near 280°C. The oxide crystallizes rapidly in sealed tubes at this temperature. On the other hand, it crystallizes exceedingly slowly from nearly anhydrous melts. J.B.A.

System zinc oxide–titanium dioxide. Zinc orthotitanate and solid solutions with titanium dioxide. S. S. COLE AND W. K. NELSON. *Jour. Phys. Chem.*, **42** [2] 245–51 (1938).—The size of the unit cell of zinc orthotitanate was checked by X-ray diffraction methods and found to be 8.46 Å. The solid solution of titanium dioxide in zinc orthotitanate extends to the composition $Zn_2TiO_4·1.5TiO_2$, the spinel structure persisting. This solid solution is not stable above 775°C, dissociating into titanium dioxide and a solid solution poorer in titanium dioxide. The initial temperature of reaction of titanium

dioxide with zinc oxide is about 430°C, the product of reaction being a solid solution with unit cell size the same as that of the lower limit of the solid solution. The specific gravity of zinc orthotitanate was found to be 5.12 and calculated to be 5.28. Titanium dioxide will react with zinc orthotitanate in the stable range of the solid solution to yield a product richer in titanium dioxide. Zinc orthotitanate was the only compound found in the composition range studied. C.J.P.

Use of bromate in volumetric analysis: VII, Potentiometric titration of hydroxyquinoline. G. F. SMITH AND R. L. MAY. *Jour. Amer. Ceram. Soc.*, **22** [1] 31–33 (1939).

Volumetric determination of cerium in rare earth oxide mixtures. V. G. SCHTSCHERBAKOV. *Zavodskaya Lab.*, **6**, 160–61 (1937).—A 0.25 to 0.3 g. sample is moistened with a small amount of water, and 50 ml. of H_2SO_4 (1:1) and 2 ml. of 3% H_2O_2 are added. After it is boiled until a great deal of H_2SO_4 vapor appears, the solution is cooled, is poured in a bottle containing 100 ml. of cold water, and is again cooled. The solution obtained is neutralized with ammonia, and H_2SO_4 is added to obtain a 1% (by volume) sulfate solution. Ammonium persulfate (1 g.) is added; it is boiled and then cooled to 50°. More ammonium persulfate (2 g.) is added and boiled an additional 5 min. After cooling, 1 g. ammonium persulfate and 20 ml. of 20% H_2SO_4 are added and boiled until all excess ammonium persulfate is decomposed; water is then added. After cooling, a 0.1 *N* H_2O_2 solution is added until the yellow coloring disappears. A little more H_2O_2 is added, and the excess is quickly titrated with a 0.1 *N* sodium permanganate solution. P.B. & E.S.

Volumetric method for the determination of cobalt. L. CALLEGARI. *Atti Soc. Sci. Lett. Genova*, **1**, 222–25 (1936); *Chimie & Industrie*, **39** [3] 447 (1938).—This process is based on the oxidation of the cobaltous salt into the cobaltic salt. Soda is added to the solution containing the cobalt salt until the reaction is clearly alkaline; hydrogen peroxide is then added to 12 vol. The liquid is heated to decompose the hydrogen peroxide completely (one drop of the liquid must not turn "iodura-midonné" paper blue). It is cooled, and an excess of a 10% solution of potassium iodide is added; HCl is then added to obtain an acid reaction. After several seconds, the brown precipitate of cobaltic hydrate is completely dissolved, and the iodine liberated can be titrated by the thiosulfate in the presence of starch paste. M.V.C.

X-ray examination for determining molecular structure and its application in ceramics. ALFRED KARSTEN. *Céram., Verrerie, Email.*, **6** [6] 181–85 (1938).—With the growing need for more complete knowledge of technical properties of materials, especially in fine ceramics, improvement in testing methods and the use of those which leave the test piece intact have been sought. The examination of ordinary structure by X-rays shows defects such as fissures and cracks; the determination of the molecular structure by X-rays shows the geometric arrangement of crystals and the modifications this molecular architecture undergoes with thermal and mechanical treatment which may cause abnormal tensions and corrosion processes, etc. X-rays are also useful in detecting mixtures, impurities, or other substances. Under certain conditions, X-rays have the property of being refracted and reflected like light rays and can be photographed. If the tiny crystals in a material have no definite direction, they form a series of lines which appear regularly black in all their length on the photographic plate. If, however, there is a certain orientation of crystals, the rays are reflected in certain directions more strongly than others and present an irregular black coloration on the radio photograph, a phenomenon which is found in metal having undergone deformation. When the X-rays strike a single crystal as in the apparatus of Laue, the lines become points and correspond to the position of the crystalline surfaces in the lattice, *i.e.*, to the symmetry of the crystal. Debye and Scherrer use a group of crystals (in metals in the form of a thin wire); they do not use polychromatic X-rays which are composed of a mixture of several wave lengths but use a monochromatic ray of only one wave length. The monochromatic grouping of X-rays can be diffracted only along certain definite angles in such a way that they form clearly determined cones of rays around the principal ray; their circumferences, which are given on the film, are called lines of Debye, and the diagrams formed are called diagrams of Debye. A comparison of the roentgenograms obtained with type diagrams is easily made in the study of a material. Another method of examining molecular structure by X-rays is by reflected rays where the rays are reflected by the test piece in such a way that they are registered on films in the form of a diagram composed of concentric circumferences. Another interesting method is the turning crystal method of Debye-Sherrer which is a modification of the method by reflected ray. During the operation the specimen is turned to augment the multiplicity of the positions of the tiny crystals. The cones of reflected rays give a series of curved lines of Debye which characterize the structure. Roentgen apparatus which can be used in industrial laboratories are described. See "Progress—," *Ceram. Abs.*, **16** [1] 32 (1937). M.V.C.

BOOK

Textbook of Chemical Technology. 20th ed. OST RASSOW. Max Janecke, Verlagsbuchhandlung, Leipzig, Germany, 1938. Reviewed in *Brit. Clayworker*, **47** [555] 116 (1938).—The chapter on pottery has been reëdited; it is up to date and gives a good general view of ceramic processes within the whole framework of the chemical industry. Developments during recent years are mentioned but references are not complete. The book is valuable and can be highly recommended. R.A.H.

PATENTS

Obtaining MgO and $CaCO_3$ from dolomitic materials. W. H. MACINTIRE (American Zinc, Lead & Smelting Co.). U. S. 2,137,675, Nov. 22, 1938 (Dec. 11, 1935).

Process for the manufacture of a sodium silicate-containing product and the resulting product. PENNSYLVANIA SALT MFG. CO. Brit. 494,628, Nov. 9, 1938 (March 18, 1937).

Producing crystalline boric oxide. LEON MCCULLOCH (Westinghouse Electric & Mfg. Co.). U. S. 2,137,058, Nov. 15, 1938 (July 31, 1937).

General

Ceramic defects and their correction. B. SPITTA. *Keram. Rundschau*, **46** [4] 37–40; [5] 50–52; [6] 60–62; [7] 70–72; [8] 83–84; [12] 133–34 (1938).—S. gives a symposium on ceramic defects reprinted from Taschenbuch für Keramiker, 1937. F.E.V.

Clay exhibits at Cooper Union Museum. ANON. *Bull. Amer. Ceram. Soc.*, **17** [12] 488–89 (1938).

Combating silicosis in the iron and metal industries in foundry operation. JACOBI. *Giesserei*, **25** [18] 427–29 (1938).—The particular points in the German regulations for prevention of silicosis in the metal industries as applying to foundry operation are reproduced and discussed. M.H.

Duration of work in high temperatures and with high humidity. O. EHRISMANN AND A. HASSE. *Arch. Gewerbepath. & Gewerbehyg.*, **8**, 611–38 (1938).—The authors deal with the lessening of working capacity due to high temperature and high humidity conditions, such as are experienced by depth miners, and the loss of water-content from the skin and the lungs under these conditions. The conclusions reached are that (*a*) neither a high temperature which is dry nor a humid temperature as such is decisive for reduction time in working, and (*b*) decrease in working power from high temperature conditions appears to be a continuously fluctuating matter, so that any definite temperature, like the 28° selected as a full-

time labor limit in the German hard-coal industry for dry atmospheric localities, is an arbitrary limit. In general, working capacity seems to be lowered by high temperatures to 60% values. The physiological reactions of men continually vary when climatic conditions grow constantly worse. Injury to health from dry and high temperatures alone can not be definitely established, the relation to humidity present always being a factor. Omitting the heat factor, a humidity of 25° seems endurable. In regard to the elimination by the skin or lungs under high and humid conditions, results appear personal and individual. Greater water elimination occurs in men acclimated to hot humid air than in those not inured. Men habitually rather than occasionally at work eliminate larger quantities of water. Rising temperatures in a dry climate and rise in humidity increase elimination of water through the skin. Individuals showed, in their elimination through the skin, none of the expected correspondences which might be traced back to these changing environal states. In this investigation, bodily temperatures generally rose very little proportionally under higher outside temperatures and increased humidity. Blood pressure, respiratory frequency, and pulse frequency showed no quantitative relation to selected climatic conditions. Fourteen diagrams and two tables are given. 18 references. K.R.

Dust content in an asbestosis lung and the behavior of the so-called asbestosis bodies. N. SUNDIUS AND A. BYGDEN. *Arch. Gewerbepath. & Gewerbehyg.*, **8**, 26–70 (1937–1938).—This research upon the effects of asbestos dust when breathed in by industrial workers in asbestos was carried out by the State Geologist and the State Chemist of the Swedish Geological Survey. They indicate the differences between the asbestosis lung and the silicotic, the former being due to the action of a basic silicate (isotropic), accumulating in yellowish or reddish-brown needle-like masses, and the silicotic being due to quartz (SiO_2) degenerative action, exhibited in nodules and other quite different manifestations. Asbestosis was first identified in 1906 by an English physician, Montague Murray, of the English Compensation Committee of Industrial Diseases. The chief research studies since that time are reviewed by these authors in their cumulative value. Their own procedure in isolating asbestos dust and its accompanying "asbestosis bodies" by treating the affected lung substance with hydrogen peroxide, also by purely mechanical action upon a "heavy" solution, is given together with the ascertained percentage values derived chemically from the eight or more mineral components of asbestos. For the entire lung, approximations were 5.6 g. asbestos bodies, 0.8 free asbestos needles, and 1.4 total asbestos content. Total dust respired by the given lung was about 2.8 g. Some of the bodies built up in needle form were composed of titanium oxide (TiO_2). Intensive study and analysis of the coverings of the bodies seem to indicate that they are blood derivatives after the mineral has entered the lung. The fibrosis ultimately and generally distributed through the lung following the dust inhalations appears to have definite relation to the presence of the asbestos needles and their movements about the lung under the mechanical stimulation due to respiratory movements. 12 photomicrographs. K.R.

Heinrich Ries. ANON. *Bull. Amer. Ceram. Soc.*, **17** [12] 490–91 (1938).

History of glass industry at New York World's Fair. ANON. *Bull. Amer. Ceram. Soc.*, **17** [12] 489 (1938).

Hygienic dangers of nonferrous metals. H. BERGER. *Metallwirtschaft*, **17** [32] 863–67 (1938).—B. discusses the dangers in handling Pb, Hg, Zn, Cd, As, Yb, Se, Te, Cr, Ni, Cu, Mn, light metals, W, Tl, and Os due to inhalation of dust or vapors or contact with each individual metal and means for eliminating or at least minimizing the risk. M.H.

Lung findings in foundry workers. O. A. SANDER. *Amer. Jour. Pub. Health*, **28**, 601–609 (1938).—Of the various occupations in foundries, sandblasting is the most hazardous if done without protection; otherwise sand chipping and grinding of large castings are the most dangerous in regard to the health of the employees. Data obtained during a four-year survey are as follows:

Years exposure	No. employees	Silicotic (%)
1– 5	1174	0.5
6–10	812	3
11–15	602	5
16–20	532	10
21–25	365	15
26–30	268	22
31–40	215	21
41–50	47	21

From this data, S. concludes that simple silicosis as seen in foundry workers is only very slowly progressive, so much so that no visible changes appeared in four years observations, and is only rarely sufficiently advanced to cause symptoms and incapacity for work. Control of the foundry hazard is best accomplished by elimination at its source of the dust generated by sandblasting, sand chipping, sand grinding, and shake-out operations. Preemployment and periodic examinations are essential to prevent tubercular individuals from carrying on a dusty trade and to discover new infection and reactivation cases as they arise. B.C.R.

Selenium as a potential industrial hazard. H. C. DUDLEY. *U. S. Pub. Health Repts.*, **53** [8] 281–92 (1938).—D. points out those industries which may have unrecognized hazards due to the possession of selenium-bearing materials. Increasing uses and applications of the element and its compounds necessitate the warning that in certain combinations selenium is toxic. Hence, industrial plants where these substances are utilized will need to afford their workers adequate protection. Selenium is obtained as a by-product from electrolytic refining of copper; this is the chief commercial source. Its first use was largely confined to the glass and ceramic industries, where it was used as a glass decolorizer and for the production of red glass and glazes. Rubber manufacturers next made heavy demands on domestic copper refineries; recent increased uses have not only exhausted domestic supplies but have required importation in larger and larger quantities. The ceramic industry alone has utilized more than 170,000 lb. According to D., new sources of supply will have to be opened. The occurrence and location in 21 states of 15 minerals, with the selenium parts per million, are tabulated. The selenium content of the earth's crust has been approximated at 0.005%; nearly all sulfur and sulfide deposits contain it; certain western phosphate rocks show amounts of even 55 parts to the million. In a large number of soil samples taken from areas surrounding smelters near Butte and Anaconda, Mont., Kennet, Calif., and Copper Hill, Tenn., selenium was found; it decreased in quantitity with distance from the smelter. Extensive animal experimentation by ingesting selenium compounds shows that such substances, when soluble, have toxic effects, both acute and chronic. Early cellular destruction occurs in the liver, with later pathological characteristic changes throughout the organism. Guinea pigs experienced severe metamorphoses in the liver and, after inhalation of hydrogen selenide, hypertrophy of the spleen. Men employed in copper refineries which extract or purify selenium display the symptoms, respiratory and gastric, which characterize metal poisoning generally. The excretion of selenium in the urine, however, is conclusive evidence of selenium absorption by workers. D. gives in detail the procedure for urinalysis in detecting and estimating selenium in the urine. In the tabulation of industries with possible selenium hazards, the glass and ceramic industries are in the secondary group, *i.e.*, they utilize selenium and its compounds as basic materials in manufacturing processes. The immediate sources of hazards involved in this group are given as melting pots and furnaces, the fumes of Se and SeO_2 being given off. The sampling of vapors and gaseous constituents of industrial plant atmospheres and contaminations of laboratory workrooms is explained in detail in connection with

illustrations of apparatus needed. Toxicological aspects of selenium hazards are discussed with respect to the extent of the hazard, conditioned, of course, by the type of processes being carried out, the solubility of selenium dust, and the mode of entry into the body. The procedure to be undertaken when workers exposed to selenium fumes or dusts show toxic symptoms is outlined. 16 references.

K.R.

Silicosis, an industrial lung disease. E. LIESEGANG. *Glastech. Ber.*, **16** [10] 328–34 (1938).—Earlier reports on various phases of the study of silicosis are reviewed.

J.F.H.

Training pottery operatives. H. W. WEBB. *Pottery & Glass Record*, **20** [10] 253 (1938).—The pottery industry is progressing so rapidly that the need for skilled technical operatives and skilled managers is extremely urgent. The technical college must supply the industry with young people trained on a much wider basis. Technical education has grown very slowly, and the authorities have been slow to recognize its importance in the industrial scheme of things, but it is now finding its place in the mind of industry and the Government, and the development should be enormous in the next ten or twenty years. The technical college can not train craftsmen to the standard of efficiency they would normally attain by industrial experience in the craft, but it can give them some acquaintance with the manual operations, a certain degree of efficiency, and a knowledge of the principles. The training most suitable for employees is a 20 weeks' course, whereby the employee attends the college as a full-time student for five months, because the technical training and the works experience are simultaneous. Junior pottery schools should be created, at which general and physical education could be continued, and the students should be introduced to the arts of pottery and be given opportunities to develop properly as workpeople in the industry. From these schools, if organized properly, the whole of the "feed" to the pottery industry would be brought. By some form of part-time education the same type of training could be continued until the students attain the age of 17 or 18. A feature essential to the success of the scheme is that schools in the future must have a model factory in which the technical, art, and craft sides are united and ware can be properly produced.

A.B.S.

BOOKS AND SEPARATE PUBLICATIONS

Industrial Health Research Board Eighteenth Annual Report. H. M. Stationery Office, London. Price 1s. The result of twenty years' work on industrial health research is summarized. The advantages of shorter working hours, of rest pauses, of planned lighting, glasses for workers engaged on fine work, and controlled humidity and the physiological effect of vibrating tools are noted. The chief work relating to ceramics is in connection with lifting loads, the use of wheelbarrows, and the best height for working benches. The results of research on vocational guidance, accident proneness, industrial sickness, psychoneurosis, and industrial pulmonary disease (including silicosis) are summarized; the effect of temperature, air velocity, and radiant heat on workers is given. The importance of adjusting the speed of presses and other machines to the individual workers is emphasized, and it is urged that the operative should be able to control the speed of the machine. Efficiency in machine feeding is dependent on the amount of feed space in the moving dial or belt and on the apparent rate of the moving mechanism. One hundred reports on health research are listed.

A.B.S.

Publications of the Kaiser Wilhelm Institute for Silicate Research in Berlin-Dahlem: Vol. 8 (Veröffentlichungen aus dem Kaiser Wilhelm-Institut für Silikatforschung in Berlin-Dahlem). Edited by WILHELM EITEL. F. Vieweg & Sohn, Brunswick, Germany, 1937. 188 pp. The book comprises papers dealing with the technology of silicates which have been published in various technical journals.

PATENT

Making vitrified products. D. E. LOWER. U. S. 2,138,870, Dec. 6, 1938 (Aug. 29, 1936). The method of making vitrified granules comprises dry grinding a blend of selected clays having selected color characteristics, adding sufficient water mixed with phosphoric acid to the ground product to produce a plastic mass, pugging the mass to effect a complete commingling of the ingredients thereof, extruding the mixed material, drying it, subsequently firing the dried extruded material to effect vitrification, and then crushing the fired material to define granules.

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